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FISHING WITH THE CORMORANT IN JAPAN

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AMERICAN MUSEUM OF NATURAL HISTORY

INTRODUCTION

I HAVE previously published[1] a historical paper on this method of fishing in the former Celestial Empire, and the present article is intended to bring together with suitable illustrations the accounts of the like use of this bird in Japan—the Land of the Rising Sun.

This method of taking fishes in China undoubtedly goes back into remote antiquity, but Chinese records are unfortunately lacking. Still one authority was found to state that it was seemingly established under the Sung dynasty, somewhere between A. D. 960 and 1288. However, as will be shown later herein, it seems not improbable that cormorant fishing was carried on at a much earlier date. The first European who saw it was Friar Odoric, of Pordenone, and the first printed account is in his book "Odorichus de Rebus Incognitis," Pesaro, 1513. It was, however, a well-established custom in China at the time of his visit (1325–1328).

For Japan, in contrast, definite notices of fishing with the cormorant are found in two early chronicles. In A. D. 682 the Emperor Tem-mu had the existing chronicles examined critically, digested and set out in definite form by a scribe named Hiyeda no Are. Tem-mu died before this was finished, but twenty-five years later the Empress Gemmio had Are collaborate with one Yasumaro, a court noble, in the final production of the "Kojiki" (Records of Ancient Things) in A. D. 712. This remained in manuscript until first published in Japanese in 1644, since which time numerous editions in the native language have appeared.

The "Kojiki" probably had its source in large part in the similarly named "Kiujiki" or "Kujiki" (Chronicles of Old Matters), which was compiled in A. D. 620 but was almost completely destroyed by fire about or shortly after 645; or at any rate in the remnant of the above saved from the flames and known as "Kokuki" or national annals. The "Kojiki" was translated into English by Basil Hall Chamberlain, published in 1882 and republished in 1920. From this latter publication the citations, presently to be given, are taken.[2]

The other work indicated above is the "Nihongi" (Chronicles of Japan from the Earliest Times). This was completed and submitted in A. D. 720 to the Empress Gemmio by Prince Toneri and the same Yasumaro referred to above. The

[1] E. W. Gudger, "Fishing with the Cormorant: I. In China," *American Naturalist*, 60: 5–41. 16 figures. 1926.

[2] Basil Hall Chamberlain, "Ko-ji-ki: Records of Ancient Matters" (trans.), *Transactions Asiatic Society of Japan.* Tokyo. Supp. to vol. 10, pp. 167 and 176. 1920. This is a reprint of the original article of 1882.

—*Courtesy of Gifu Municipal Office*

FIG. 1. A FLOTILLA OF SIGHTSEEING BARGES

DRAWN UP AT THE LANDING PLACE ON THE NAGARA RIVER, GIFU. THEY ARE READY TO CONVEY TOURISTS TO THE CORMORANT-FISHING GROUNDS.

"Kojiki" seems to be almost wholly Japanese in origin, but the "Nihongi," which is based largely on the "Kojiki," on other chronicles and various scattered records, is said to show many traces of the strong Chinese influences then prevalent at the court of the Empress Gemmio. It is, moreover, very much larger than the "Kojiki." The "Nihongi" has passed through many editions. The one quoted herein is the English version by W. G. Aston, published in 1896.[3]

With these brief historical remarks, quotation will now be made of the earliest known accounts of fishing with the cormorant in Japan. There are two citations in the "Kojiki," both found in the accounts of a journey eastward through his domain of the Emperor Jim-mu. The first is found in volume 2, section 46, and reads as follows:

> So on making his progress . . . he reached the lower course of the Yeshinu [Yoshino] River, where there was a person catching fish in a weir. Then the august child of the Heavenly Deity [the Emperor] asked, saying "Who art thou?" He [the fisherman] replied, saying: "I am an Earthly Deity and am called by the name of Nihe-motsu no Ko." This is the ancestor of the cormorant keepers of Aha.

The second reference, and a very definite one, is found in book 2, section 49. Here, when the Emperor Jim-mu had fought and had smitten both Shiki the Elder and Shiki the Younger, he and

[3] W. G. Aston, "Nihongi: Chronicles of Japan from the Earliest Times to A. D. 697" (trans.), *Transactions and Proceedings Japan Society*, London, vol. 1 (Suppl. 1), pp. 119, 126, 341. The reader interested in the history of these old chronicles will find full discussions in the introductions to the works of Aston (1896) and Chamberlain (1920).

his army were faint for want of food and he sang this song:

As we fight placing our shields in a row, going and watching from between the trees on Mount Inasa, oh! we are famished. Ye keepers of cormorants, the birds of the island, come now to our rescue.

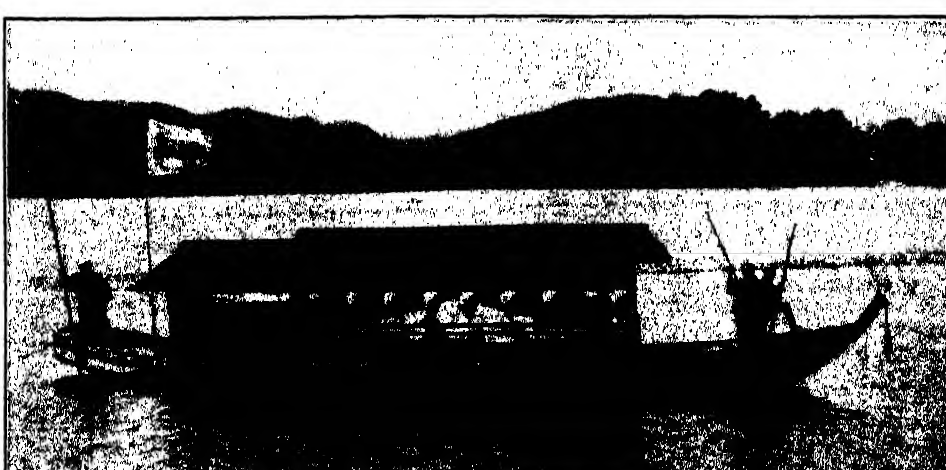
Chamberlain's note on this is: "This song is a request for provisions made by the emperor to some fishermen who were working the cormorants along the mountain streams." Here, then, we have a plain indication of the use of the cormorant as a fisher long before A. D. 712.

In the "Nihongi" (A. D. 720), in book 3, section 15, is found in almost identical language the incident quoted above from the "Kojiki." But the explanatory statement here reads of Nihemotsu that, "He it is who was the first ancestor of the U-Kahi of Aha"—the word U-Kahi meaning cormorant keepers. Again on page 126 (book 3, section 24), the song of the emperor is set in (modern) poetic form thus:

As we fight
Going forth and watching
From between the trees
Of Mount Inasa,
We are famished.
Ye keepers of cormorants
(Birds of the island)
Come now to our aid.

And finally (book 14, section 12) where the scene is located on the River Ihoki, there is found the statement that the Emperor Oho-hatsuse Wakatake persuaded one Takehiko to go with him to the river, and "There, pretending to make cormorants dive into the water to catch fish, he took him unawares and slew him."

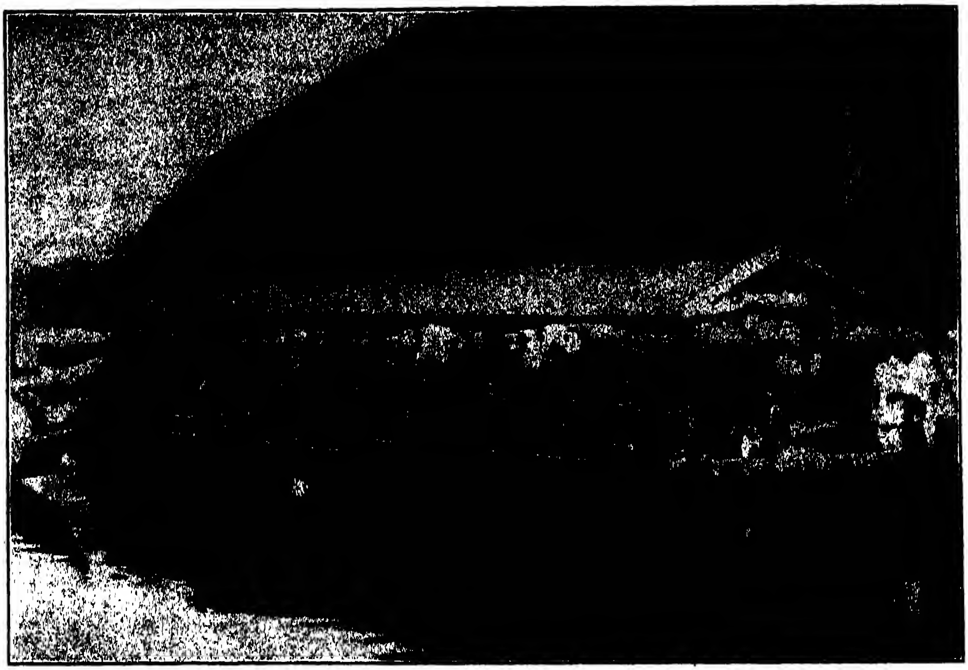
These citations show that fishing with the cormorant was practiced in Japan, perhaps in prehistoric days, certainly long before A. D. 612. Whether this practice arose spontaneously in Japan or whether it was brought from China can not be stated definitely. However, since most students of the Orient think that the early culture of Japan had its source in China, it seems not improbable that this method of fishing was imported from China at a very early date. How this importation was made is not certainly known, but one can infer that, in



—Photograph by Dr. H. M. Smith

FIG. 2. A SMALL BARGE

FROM WHICH TO VIEW CORMORANT FISHING AT GIFU ON THE NAGARA RIVER.



—*Photograph by courtesy of Gifu Municipal Office*

FIG. 3. A LARGE BARGE

USED TO CONVEY THE SPECTATORS FROM GIFU TO AND ABOUT THE CORMORANT-FISHING GROUNDS. NOTE THE KITCHEN IN THE REAR.

the early diplomatic intercourse between China and Japan, cormorants may have been carried from the former to the latter country.

That there was such early intercourse is made clear by Hervey Saint-Denys (1871) in his critical memoir on the "Ouen Hein Tong Kao" (Profound Researches into Ancient Monuments) of Ma-Touan-Lin.[4] This great Chinese scholar and critic composed his encyclopedic work in the thirteenth century A. D. His chronicle covers the history of China from about 2400 B. C. to about A. D. 1300. In it he records periodical Chinese embassies to Japan from about A. D. 200 on. Hervey Saint-Denys works out the dates of certain early embassies as of A. D. 246, 416 and 425—from which latter time on they were frequent. More to our matter the French critic quotes Ma-Touan-Lin that:

> The inhabitants [of Japan] dive into the water to catch fish. They also have cormorants with the neck of each surrounded by a little ring to prevent swallowing, and they train them to catch fish. In this way they take in a day several hundred fish.

If now the commonly held belief be accepted that Chinese culture and civilization (including the use of the cormorant in fishing) antedated that of Japan, then, since we have dates for the sending of Chinese embassies to Japan, we need not find it difficult to believe that the Japanese learned this method

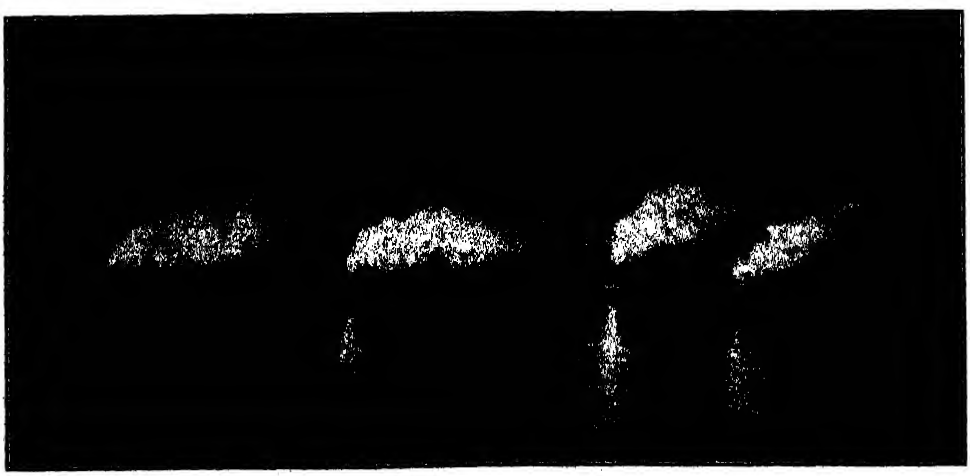
[4] Hervey Saint-Denys (Marquis de), "Ma-Touan-Lin. Ethnographie des peuples étrangers à la Chine, Ouvrage composé au XIIIe siècle de notre ére par Ma-Touan-Lin." Genève, "Orientaux," p. 79 (trans.), 1876; "Mémoire sur l'histoire ancienne du Japon, d'après le Ouen Hien Tong Kao de Ma-Touan-Lin," *Journal Asiatique,* Paris, 6. series, tome 18, pp. 386 and 403. 1871.

of taking fish from the Chinese, and indeed possibly got their first birds from these embassies.

Both Aston and Hall affirm that fishing with the cormorant in Japan was a common thing during the Middle Ages and up to the Renaissance, but other records filling in the gap between the distant past and the comparatively recent years are few. So far as I have searched, unlike similar works for China, none of the early European voyagers to Japan, not even Kaempfer, figures or even refers to cormorant fishing in Japan. The explanation for this is to be found in the fact that Japan is largely mountainous with little plain or flat country (as in China) near the ports. Cormorant fishing in Japan seems always to have been practiced only in a few upland or mountainous sections to which the early voyagers probably never penetrated.

In fact, the only early accounts additional to those given above have been found in articles on cormorant fishing in the Land of the Rising Sun by two Japanese scholars, Ikenoya (1917) and Kuroda (1926). The latter was commissioned by the imperial government to investigate and write up this fishing in Japan, and from the data thus officially obtained the article referred to (1926) was prepared. The former alleges that cormorant fishing was carried on during the Heian era in the province of Mino—no river specified, though it is probable that this was the Nagara as noted below. All the other citations of this fishing locate it more narrowly and will be set out by regions.

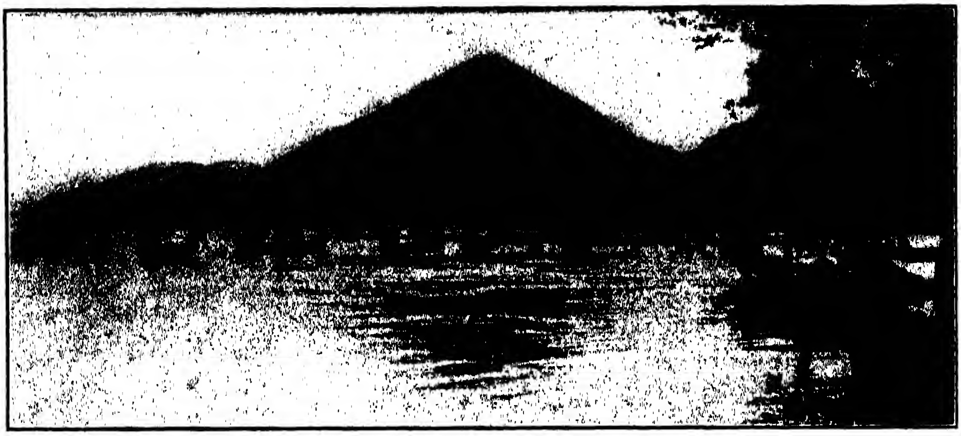
While cormorant fishing in China is purely a commercial proposition, carried on throughout the entire length and breadth of the great plain of China, in Japan it is practiced only in certain restricted localities and there partly as a business but largely as a matter of sport intended to attract tourists. In China, as my previous studies have shown, this fishing is carried on only in the daytime. But in Japan, in keeping with its sporting character, it is carried on mainly at night, in one locality in both night and day, and occasionally (as a commercial proposition entirely) in some sections in daytime only. Furthermore in Japan the birds seem to be



—Picture by courtesy of Gifu Municipal Office

FIG. 4. THE FISHING BOATS DRIFT SLOWLY DOWN THE STREAM

THEIR LIGHTED CRESSETS GIVING REMBRANDT-LIKE EFFECTS IN THE INKY DARKNESS.



—*By courtesy of Gifu Municipal Office*

FIG. 5. DISTANT VIEW OF THE CORMORANT FISHING
ON THE NAGARA RIVER, THE BARGE WITH SPECTATORS IN THE RIGHT FOREGROUND.

used for taking practically only one fish, the *ayu* or sweet-fish, *Plecoglossus altivelis,* a salmonid reaching about a foot in length and found only in the clear upland and mountain streams of central Japan. Since the accounts of this fishing specify the use of the birds on certain streams only, my data will be presented under these locality headings, beginning with that one where it has been longest carried on and is to-day most prosecuted.

FISHING WITH CORMORANTS ON THE NAGARA RIVER FROM A. D. 900 TO 1877

It seems well to segregate the old accounts of fishing on this river from the recent ones. The former are very fragmentary, the latter very detailed. The former are interesting historically, while the latter are delightful accounts of a most attractive fishing method.

The earliest record I find (on the authority of Kuroda) is that during the Engi era (A. D. 901–922) there were seven cormorant fishers' cottages on the Nagara. From their catches dried *ayu* were sent to the imperial court by Toshihito Fujiwara, governor of Mino province. During the Jimpei era (1151–1153) it is recorded that these cottages had increased to twenty-one in seven villages. In 1159, the first year of the Heiji era, Yoshitomo Minamoto put up a cormorant fisher's cottage on the lower Nagara River, and received tribute of the fishes caught. Again in 1190 it is on record that a cormorant fisher sent to the same official presents of "sugared sweet-fish and rice," thus establishing the custom. And later Zenkakei Kaneyashi Ichigo was present at a cormorant fishing in the Nagara in the Bummei era (1469–1486), about the time when Columbus was seeking aid for his westward voyage to the Indies.

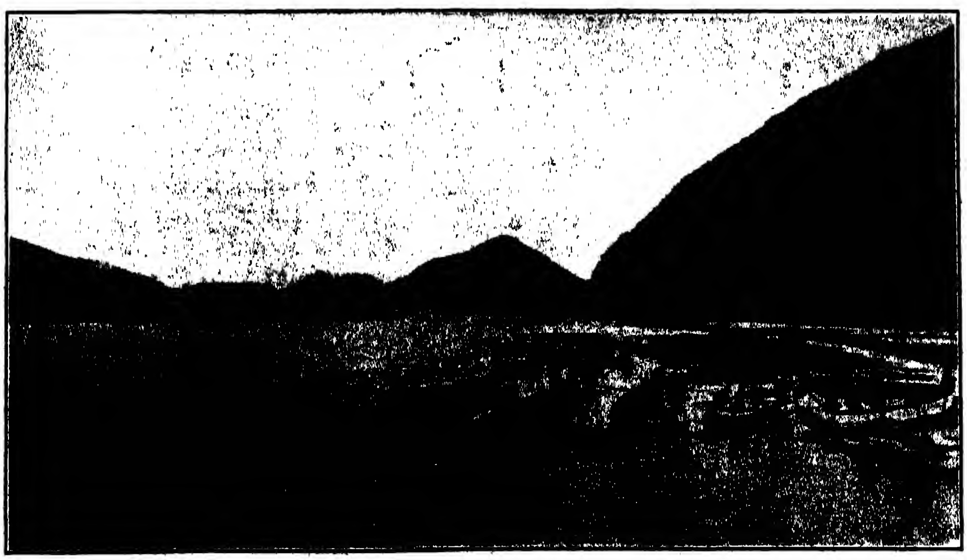
In 1504 it is said that there was in one of these villages on the Nagara a girl named Ako who was reputed to be very skilful in the handling of cormorants, as is evidenced by her driving twelve at once (note the number twelve which is the normal number for a master cormorant fisher to-day). "This lady of old is regarded as the mother of *ugai* (cormorant fishing)" (Ikenoya). In 1564 (the seventh year of Eiroku), Nobunaga Oda saw the fishing near

Gifu, raised the cormorant fishers to equivalent rank with the falconers, giving each fisher the title *U-jo*, or cormorant tamer, and gave each family a pension in the form of a bag of rice each month and the present of a new boat every four or five years.

For the 1600's we have numerous references. In the opening year of the century (the fifth of the Keicho era), certain troops advanced into the valley of the Nagara and their commander ordered the cormorant tamers to serve as porters for his army. They refused and all their houses were burned. However, three years later, Iyeyasu Tokugawa was presented with the products of the fishery, and in 1615 (first year of the Genna era) he visited Gifu and was greatly pleased with the cormorants at work. On leaving he ordered the *ugai* men to send fish to Yedo twice a month during the season, and this was also required by his successors for many years—there is a record for 1665. The fish were packed in kegs and reached Yedo in two days' time.

In 1707 (fourth year of the Hoyei era) definite family names were conferred on the three chief cormorant tamers. In 1808 (fifth year of Bunka era), the cormorant tamers had been reduced to twelve (a number having left off this fishing), and these received specified allowances of rice and money. In 1867 they were ordered to send a definite tribute of pickled *ayu* to Kyoto, but in 1873 the preferential treatment afforded them was abolished and they were ordered to pay an *ayu*-fishing tax directly to the Gifu prefecture.

In 1878, and again in 1880, the Emperor Meiji visited Gifu and saw the fishing, and in 1888 or 1890 he issued a decree setting aside three imperial fishing places on the Nagara. These were attached to the Grand Veneur's Bureau of the Imperial Household Department. These are: the lower at Furutsu, Nagara-mura; the middle at Tachibana,



—*After Pichot, probably from Layrle*

FIG. 6. ANOTHER VIEW OF CORMORANT FISHING
IN A WIDE REACH OF THE NAGARA RIVER NEAR GIFU.

—*After Mrs. Cochrane, by courtesy of "Asia"*

FIG. 7. THE CORMORANT TAMER

HOLDING THE REINS IN HIS LEFT HAND, HE TAKES THE BIRD'S NECK IN HIS RIGHT AND MAKES IT DISGORGE ITS CATCH.

Suhara-mura, and the upper at Ueda, Takeda-mura—all in Gifu prefecture. In 1921, these imperial fishing places were placed under the jurisdiction of the hunting section of the Imperial Household Department.

Here then we have an epitomized sketch of the history of the fishing on the Nagara River as contained in Japanese records and written down by Kuroda (1926). He further states that since the Meiji restoration the witnessing of cormorant fishing on the Nagara has become a fashionable recreation, attended at times by the emperor and his household, by distinguished visitors from abroad, as well as by many native visitors—numbering many thousands each year. This fishing will now be described.

PRESENT-DAY FISHING AT GIFU ON THE NAGARA RIVER AT NIGHT FROM BOATS

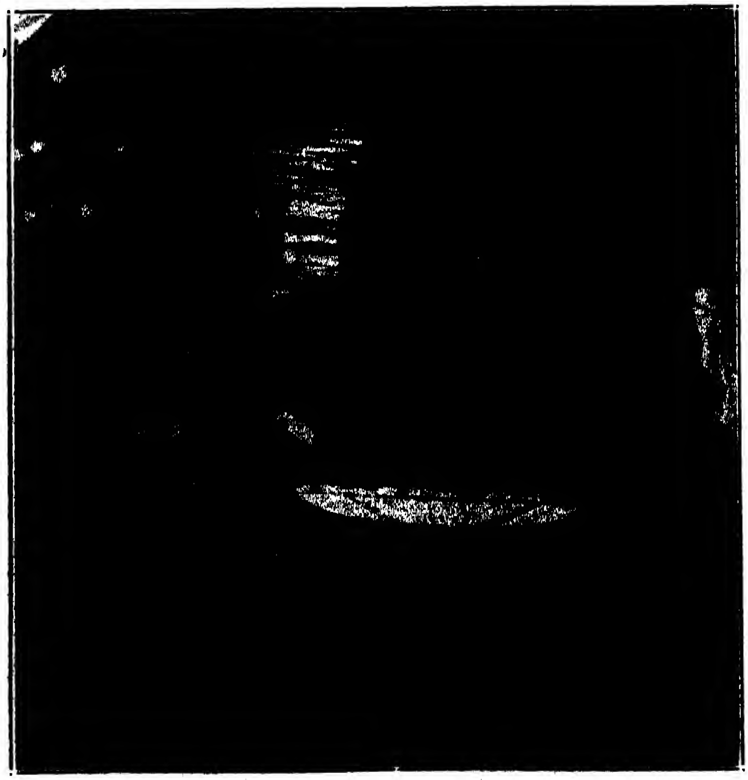
Gifu, a city of some 50,000 inhabitants, is situated on the Nagara River in south

central Japan. This river is formed of four tributaries which rise in the slopes of Mt. Dainichigatake, and in the greater part of its lower course is navigable for small boats. It empties into Owari Bay.

The earliest printed account known to me of fishing on the Nagara, and indeed of cormorant fishing in all Japan, excepting the printing in Japanese of the old chronicles noted above, dates back no farther than 1877. In this year Gregory published an article[5] in which he describes this fishing with cormorants in the Nagara. He explains that the cormorants are caught on the island of Susashima in Owari by placing wooden images of them in places which they frequent, and by covering the branches of the nearby trees with birdlime. One cormorant caught, others are attracted and in turn are caught. Then he continues as to their use that:

> Near the Nagara River are seven houses, the occupants of which are employed in fishing with cormorants. In each of these houses are kept, on an average, sixteen birds. From the first of the fourth month until the end of the eighth month fishing in the River Nagara is carried on every night. The fishermen go out in long boats which at their bows are furnished with fire baskets or cressets. The fish having been attracted by the light from the fires in these, the birds are sent into the water.

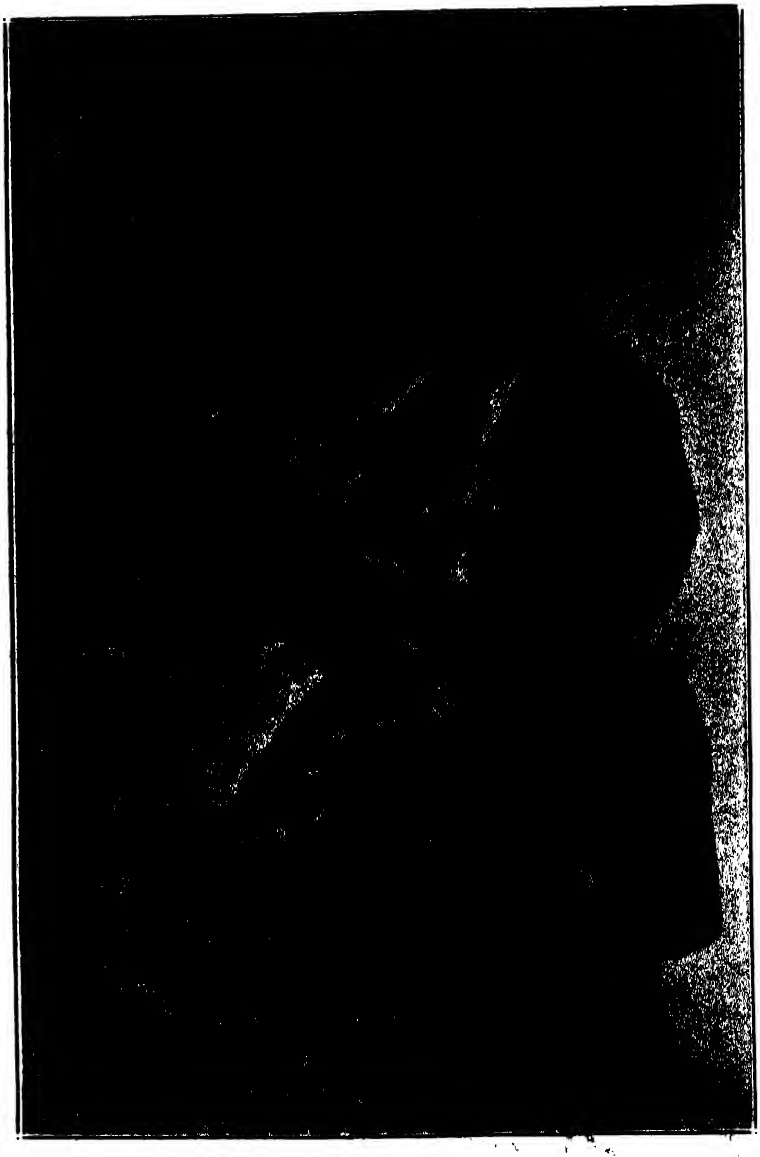
[5] George Elliott Gregory, "Japanese Fisheries," *Transactions Asiatic Society Japan*, Yokohama, 5: 102–113. "Cormorant Fishing," pp. 110–111. 1877.



—*Photograph by Dr. H. M. Smith*

FIG. 8. THE HEAD FISHERMAN AND HIS ASSISTANT

PUTTING THE HARNESS ON ONE OF THE BIRDS. THE BASKETS ARE TWO-CHAMBERED AND HOLD TWO CORMORANTS EACH.



—*After Mrs. Cochrane, by courtesy of "Asia"*

FIG. 9. HARNESSING THE CORMORANTS AT GIFU

NOTE THE STANDARDIZED METHOD. THIS PICTURE WAS TAKEN MORE THAN TWENTY YEARS LATER THAN DR. SMITH'S.

The cormorant, after having caught a fish, is drawn into the boat, and, the fish being taken from it, it is sent into the water again. Large *ayu* fish weigh as much as three quarters of a pound and the cormorant often swallows five or six fish of this weight. Thus in an hour's time one boat often takes two hundred fish. Very much, however, depends upon the skill of the fisherman, the tying up of the necks and bodies of the birds so that they be neither too tight nor too loose, and upon the care taken in giving the birds the proper quantity of food.

Gregory also describes the method of training the cormorants, the earliest known to me for Japan. He writes that:

From the commencement of the ninth month (October 3) until the commencement of the fourth month (May 7) of the following year the birds are fattened. As above mentioned the houses in which cormorants are kept amount to seven, possessing a total of about one hundred and twelve birds. These are trained in the following manner. All the one hundred and twelve birds are sent off together on the River Nagara; the fishermen encouraging them to fish by uttering cries of *Aika! Aika!* The birds dive and catch and eat fish of all sizes (at this time their necks and bodies are not tied up); after having eaten enough they are driven together by help of the boats, none ever escaping. Each of the owners then picks out his own birds from the flock, recognizing them by their heads, and takes them into his boat. Should it happen that a bird strays, the fisherman recalls it by crying *Ko, ko, ko!* at the same time holding up a fish which he gives to it on its return. The birds are fed but once a day and in the manner just described. Trained birds have a cord tied round their necks to prevent them from swallowing the fish entirely, but they are able to swallow small fish notwithstanding. It is not necessary, if they have been out some time, to give them any other food. In the night after having finished fishing in the river, should any of the birds evidently still be hungry they are fed with fish. After this all the birds are taken to their quarters, when it is necessary, however, to tie a piece of cord (made of straw) round their necks to prevent them from vomiting the fish they have taken for food. Every day at about ten o'clock the birds are placed four together in baskets and conveyed to the river to drink.

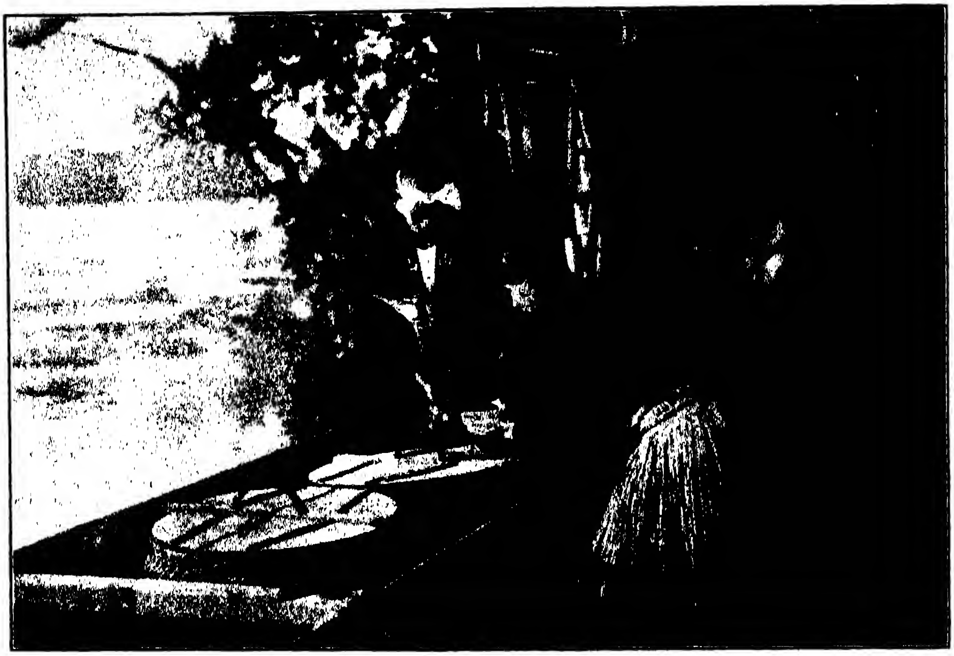
In summer to protect the birds from the mosquitoes, which would otherwise trouble them very much, their quarters are surrounded with mosquito nets.

The next account I have found is in the London *Times* for August 21, 1889 (p. 4). This is labeled "From our Tokio correspondent" and is without signature, but Basil Hall Chamberlain (previously referred to) in his book, "Things Japanese,"[6] quotes this account and attributes it to a Major-General Palmer, Royal Engineers. This account is such a very detailed and interesting one and one so evidently written by an eye-witness that it will be liberally quoted. Palmer writes that a dark night should be chosen and that the river should be free from turbidity. On such a night his party embarked on a beautifully decorated, equipped and be-lanterned, roomy barge, having a tiny kitchen for providing the sightseers with fruits, sweetmeats, hot tea and "spitchcocked eels piping hot." Such a fleet of barges,[7] plentifully bedecked with pennants and with Japanese lanterns, is shown in Fig. 1. These are drawn up on the shore of the Nagara River at Gifu and are ready to take tourists up the river at night to witness the cormorant fishing. Such a single barge is portrayed in Figs. 2 and 3. Thus equipped, the attendants poled and towed the barge with the sightseers up the Nagara until finally it was anchored to await the coming of the piscatory craft of the cormorant tamers. We will let Palmer describe the scene in his own words:

Presently the first sign is detected—a spot of hazy, red glow, shining over the trees from a reach two or three miles above us. Hereupon our chief boatman erects his private signal—a mighty paper lantern of a red and white basket pattern. Steadily the glow spreads and deepens, until, as the last intervening point is cleared, we descry its cause—a constellation of shifting, flickering lights, drifting down the dark river towards us. By degrees these develop into balls of fire, seven in number, casting as many long coruscations of light before them, from their reflection on the waters of the stream. Then sounds are heard—sounds of much beating, shouting and splashing. Next appear the forms of boats and the swarthy figures of men thrown up with weird, Rembrandt-like effects against the inky blackness of

[6] Basil Hall Chamberlain, "Things Japanese." Tokyo, 1898. "Cormorant Fishing," pp. 95–98.

[7] For this and many other pictures used herein, I am under obligation to the authorities of the Gifu Municipal and Prefectural Offices, who sent large numbers of pictures together with descriptive literature (largely in Japanese).



—*Photograph by courtesy of Gifu Municipal Office*

FIG. 10. THE FISHERMEN'S BOAT

DRAWN TO SHORE IN A QUIET COVE WHILE THE BIRDS ARE BEING MADE READY FOR FISHING.

the night; and in the water round about the boats are numbers of cormorants, behaving to all appearance in the maddest fashion. The fires, we now see, are great cages of blazing pine-knots, suspended over the bow of each boat, darting forth flames and sparks, and forever dropping embers, which fall with loud hissing into the stream. Nearer still they come. The men have seen our signal, and are manoeuvring so as to surround us; which being done, we find ourselves in the midst of the uproar and excitement of cormorant-fishing *à la Japonaise*.

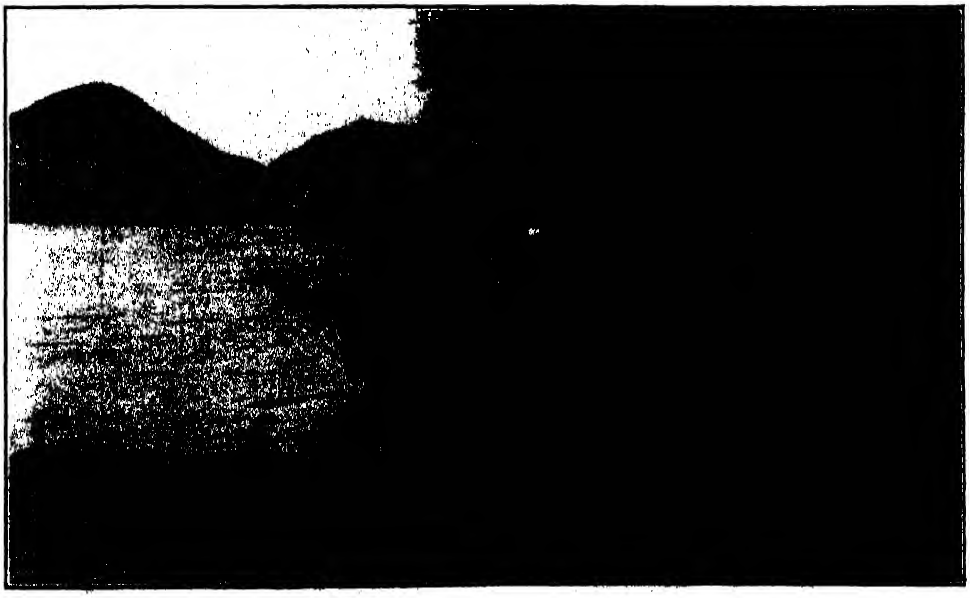
This night scene is well portrayed in Fig. 4, while Figs. 5 and 6 (evidently taken in the daytime) show how the boats and cormorants come down the river spread out so as thoroughly to cover the water. How the fishing is carried out from the boats is thus described by General Palmer:

There are, to begin with, four men in each of the seven boats, one of whom, at the stern, has no duty but that of managing his craft. In the bow stands the master, distinguished by the peculiar hat of his rank, and handling no fewer than twelve trained birds with the surpassing skill and coolness that have earned for the sportsmen of Gifu their unrivaled preeminence. Amidships is another fisher, of the second grade, who handles four birds only. Between them is the fourth man, called *kako*, from the bamboo striking instrument of that name, with which he makes the clatter necessary for keeping the birds up to their work; he also encourages them by shouts and cries, looks after spare apparatus, etc., and is ready to give aid if required. Each cormorant wears at the base of its neck a metal ring, drawn tight enough to prevent marketable fish from passing below it, but at the same time loose enough—for it is never removed—to admit the smaller prey, which serves as food. Round the body is a cord, having attached to it at the middle of the back a short strip of stiffish whalebone, by which the great awkward bird may be conveniently lowered into the water or lifted out when at work; and to this whalebone is looped a thin rein of spruce fiber, twelve feet long, and so far wanting in pliancy as to minimize the chance of entanglement. When the fishing ground is reached, the master lowers his twelve birds one by one into the stream and gathers their reins into his left hand, manipulating the

latter thereafter with his right as occasion requires. No. 2 does the same with his four birds; the *kako* starts in with his volleys of noise; and forthwith the cormorants set to at their work in the heartiest and jolliest way, diving and ducking with wonderful swiftness as the astonished fish come flocking towards the blaze of light. The master is now the busiest of men. He must handle his twelve strings so deftly that, let the birds dash hither and thither as they will, there shall be no impediment or fouling. He must have his eyes everywhere and his hands following his eyes. Specially must he watch for the moment when any of his flock is gorged—a fact generally made known by the bird itself, which then swims about in a foolish, helpless way, with its head and swollen neck erect. Thereupon the master, shortening in on that bird, lifts it aboard, forces its bill open with his left hand, which still holds the rest of the lines, squeezes out the fish with his right [Fig. 7] and starts the creature off on a fresh foray—all this with such admirable dexterity and quickness that the eleven birds still bustling about have scarce time to get things into a tangle, and in another moment the whole flock is again perfectly in hand.

This account gives the reader an excellent idea of this combined sport and business. Equally clear is Palmer's circumstantial account of the training and behavior of the birds. This gives the details entirely lacking in Gregory's brief statement. He writes that:

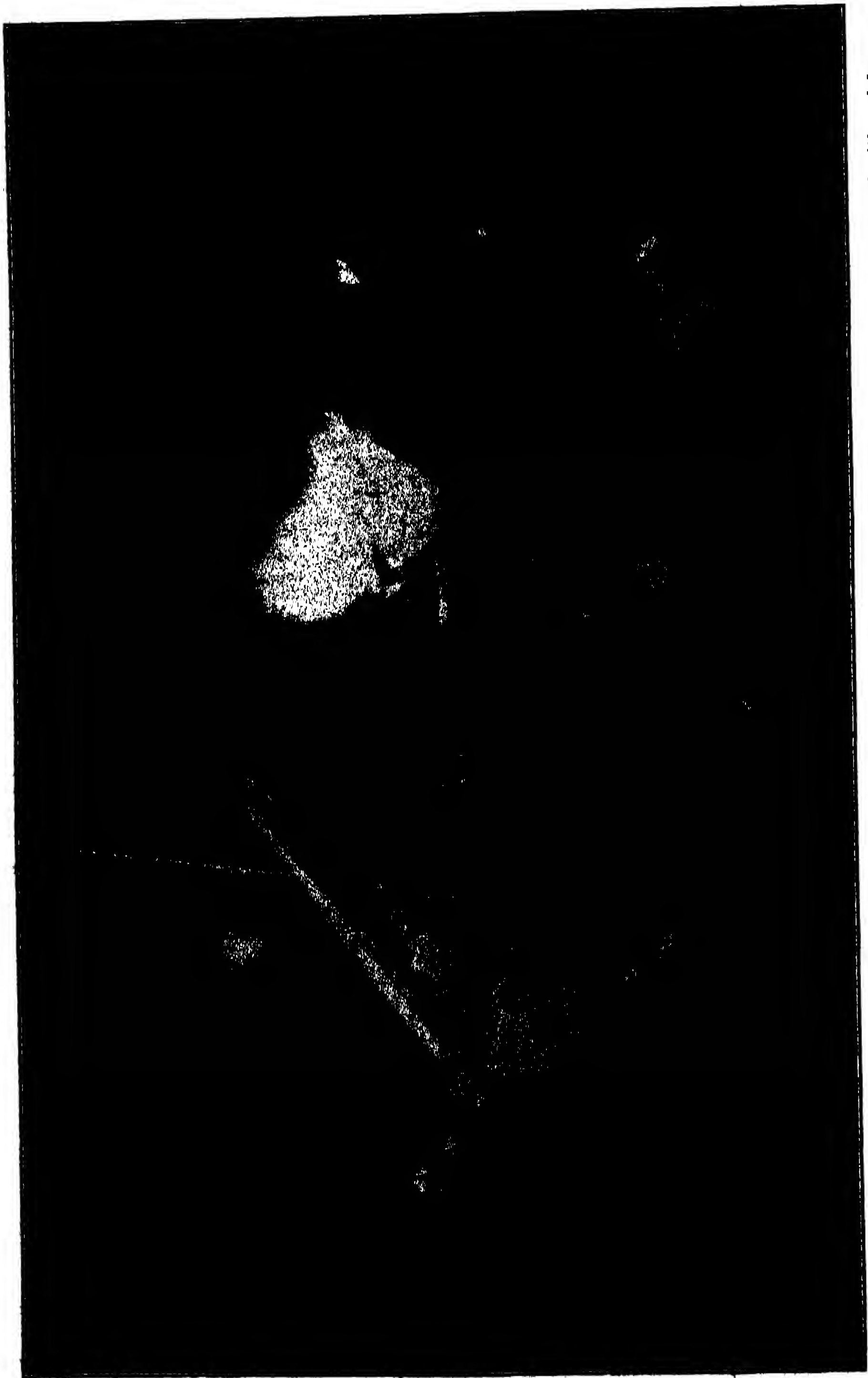
As for the cormorants, they are trained when quite young, being caught in winter with birdlime on the coasts of the neighboring Owari Gulf, at their first emigration southward from the summer haunts of the species on the northern seaboard of Japan. Once trained, they work well up to fifteen, often up to nineteen or twenty years of age; and, though their keep in winter bears hardly on the masters, they are very precious and profitable hunters during the five-months' season and well deserve the great care that is lavished upon them. From four to eight good-sized fish, for example, is the fair result of a single excursion for one bird, which corresponds with an average of about one hundred and fifty fish per cormorant per hour, or four hundred and fifty for the three hours occupied in drifting down the whole course. Every bird in a flock has and knows its number;



—Figure (posed in the daytime) by courtesy of Gifu Municipal Office

FIG. 11. A CORMORANT-FISHING BOAT

MEN AND BIRDS READY TO START OUT. THE U-JO HOLDS THE REINS IN HIS LEFT HAND AND SORTS THEM WITH HIS RIGHT. ONLY EIGHT BIRDS ARE VISIBLE.



—*Photograph by courtesy of the authorities of Inuyama*

FIG. 12. NIGHT FISHING AT INUYAMA

THE CRANE WITH ITS CRESSET HAS BEEN SWUNG ALONGSIDE THE BOAT. THE U-JO IS HANDLING NINE BIRDS. EIGHT ARE SWIMMING ON THE SURFACE AND ONE HAS DIVED IN PURSUIT OF A FISH.

and one of the funniest things about them is the quick-witted jealousy with which they invariably insist, by all that cormorant language and pantomimic protest can do, on due observance of the recognized rights belonging to their individual numbers. No. 1, or "Ichi," is the *doyen* of the corps, the senior in years as well as rank. His colleagues, according to their age, come after him in numerical order. Ichi is the last to be put into the water and the first to be taken out, the first to be fed, and the last to enter the baskets in which, when work is over, the birds are carried from the boats to their domicile. Ichi, when aboard, has the post of honor at the eyes of the boat. He is a solemn, grizzled, old fellow, with a pompous, *noli me tangere* air that is almost worthy of a Lord Mayor. The rest have places after him, in succession of rank, alternately on either side of the gunwale. If, haply, the lawful order of precedence be at any time violated—if, for instance, No. 5 be put into the water before No. 6, or No. 4 be placed above No. 2—the rumpus that forthwith arises in that family is a sight to see and a sound to hear.

But all this while we have been drifting down, with the boats about us, to the lower end of the course, and are again abreast of Gifu, where the whole squadron is beached. As each cormorant is now taken out of the water, the master can tell by its weight whether it has secured enough supper while engaged in the hunt; failing which, he makes the deficiency good by feeding it with the inferior fish of the catch. At length all are ranged in their due order, facing outwards, on the gunwale of each boat. And the sight of that array of great ungainly sea-birds—shaking themselves, flapping their wings, gaw-gawing, making their toilets, clearing their throats, looking about them with a stare of stupid solemnity, and now and then indulging in old-maidish tiffs with their neighbors—is quite the strangest of its little class I have ever seen, except perhaps the wonderful penguinry of the Falkland Islands, whereat a certain French philosopher is said to have even wept. Finally, the cormorants are sent off to bed, and we ourselves follow suit.

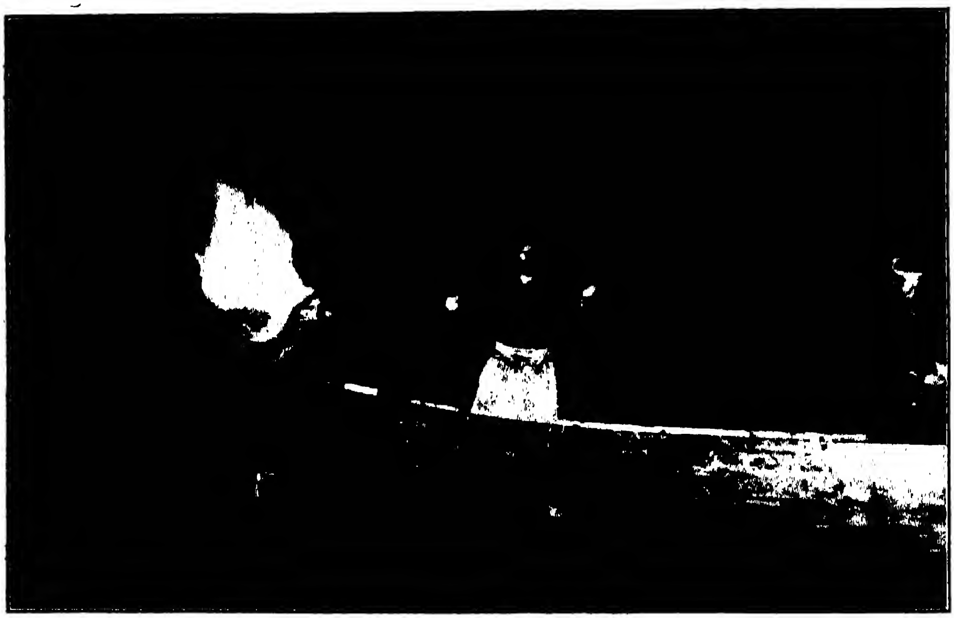
The next account that has come to hand was published in *Die Natur* in 1890. It was written by a person hiding his identity under the initials "K. M."—probably Karl Müller, one of the editors.[8] When translated this sounded very like the account from Chamberlain attributed to Palmer, and careful comparison with Palmer's letter in the London *Times* showed that it is a mere translation, alleged, however, to be made from the *London and China Express*, August 23, 1889. But no such journal is listed in the "Catalogue of the British Museum," or in the "Union List of Serials in the Libraries of the United States and Canada."

In the *Revue Britannique*[9] for May, 1891, is a spirited account of this fishing at Gifu. This also is unsigned but the editor, Pierre Amédée Pichot, in his book (1903) presently to be quoted, says that it is from the pen of an Admiral Layrle. This writer (1891) describes in interesting detail the preparation of the tourists' boat for the fête with lanterns, geishas, servants and refreshments (see Fig. 1). In these boats the visitors embark and follow the boats of the fishermen. This account, apparently that of an eye-witness, differs in some details from that given above and it seems well to reproduce here certain extracts from it. It is stated that when night comes on, preferably one without moonlight, the fishermen make their arrangements as follows:

In each fishing boat two men begin the preparation of the birds. There are twenty-four to a boat in a large cage. One of the men pulls out a cormorant by the neck and while he holds it thus suspended he strokes it or even tickles it, so that the bird, without any resistance or movement, lets a cord be attached to one of its feet. This cord crossing the stomach ends at the neck in a ring, destined to prevent the passage of a fish down the throat into the stomach [see Figs. 8, 9, 10]. The whole operation [of preparing the birds] lasts about twenty minutes. While this is being done, on a movable crane in front of each boat there is lighted a brazier of wood and straw which sheds a strong but uneven light over the river. The men are at their posts, and the cormorants in the water swim here and there, agitated and nervous among the burning sparks falling from the braziers.

8 K[arl] M[üller], "Ueber Kormoran-Fischerei in Japan," *Die Natur*, Halle, N. F. Vol. 16 (Vol. 39), pp. 31–32. 1890.

9 Vol. 67, pp. 51–60. Figures.



—*Photograph from Dr. Kuroda*

FIG. 13. THE HEAD FISHERMAN

AT THE PROW OF THE BOAT HANDLING THE LINES OF THE CORMORANTS. MOST OF THE BIRDS ARE UNDER WATER, BUT ONE IS BRINGING TO ITS MASTER THE FISH IT HAS JUST CAUGHT.

There are only four fishermen to a boat. The one towards the rear steers and controls the boat at his will; the second, armed with an oar [pole?] pushes on the bottom, on other boats or on the rocks in such a way as to send the boat in the right direction. At the two ends, standing in plain sight—the one in front almost in the flames—each of the two master fishermen directs his twelve cormorants, holding the mother cord in which end the twelve small cords attached to the birds.

With everything thus in order (Fig. 11), the fishing boats push off and with the birds drift with the current, closely followed or perhaps preceded by the belanterned boat filled with sightseers, singers and servants, as is portrayed in Fig. 3. The music and songs seem to excite the cormorants and incite them to their duty (Fig. 12). Fig. 13 shows the head fisherman standing in the bow of the boat near the cresset handling the lines of his birds, which threaten to become badly tangled.

These [birds], however, are all old hands at the business. The master follows them with his eye and handles the cords in such admirable fashion that they never become tangled in spite of the many evolutions of the birds—an aquatic pack one might say, but docile and attentive. The birds work on in all the noise and light. They swim, dive, reappear with the head high and the eyes shining, and every time with a fish in their beak. They hurry to get rid of this that they may dive again to take another, or perhaps to play a long time with a catch which they know to be only provisional. The master is there, however, and he does not let them out of his sight. He keeps account of the unusual size of the birds' throats and, without ceasing his watch for an instant, draws quickly in one which he sees is full of booty, seizes him by the neck, hangs him head down, and with a simple tap makes him disgorge instantly his part of the prey into the bottom of the boat [Fig. 7]. Five seconds at the most and the cormorant is thrown back without regard into the water, where humiliated and furious he dives at once to revenge himself on some new fish for the deception of which he himself has been the victim. A new bird is drawn into the boat and the fishing continues, the boats being always carried by the current into the midst of the disturbed feverish birds who dive in the fantastic light of the lanterns and braziers.

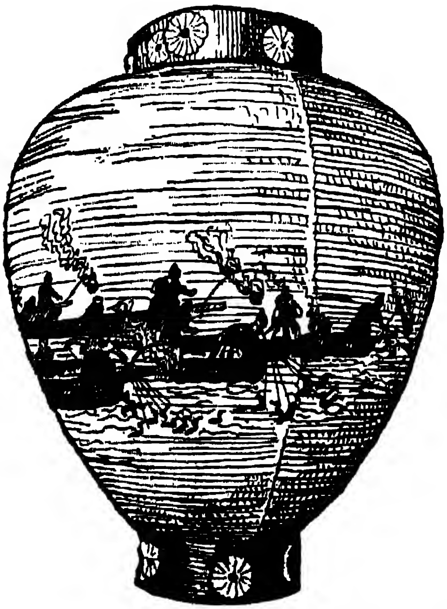
All the while the guitars make their music heard and the fishermen continue their encouraging cries. The fishing goes on without pause, obstacle or accident. There is perfect cooperation between birds, fishermen and boatmen.

The fishing ground having been covered, the party breaks up and the tourists return to their hotel, where, in case they did not partake of the *ayu* cooked on board the boat, they are likely to feast on some before retiring. Next morning when the tourists depart, the innkeeper will present them with fans having painted on them the scene witnessed over night. However, if they visit Gifu's chief industry, the factory where paper lanterns are made, such a souvenir may be procured as that shown in Fig. 14.

Pierre Amédée Pichot (editor of *Revue Britannique*) reproduces in his book, "Oiseaux de Sport"[10] the citation from Admiral Layrle previously given. He refigures Layrle's cut of the lantern showing cormorant fishing at Gifu, and also gives (source unknown) the figure showing the boats on a broad stretch of the river at Gifu, reproduced herein as number 6. This same account is also quoted by Alfred Belvallette,[11] who also gives a picture of this fishing drawn by a native artist. This is reproduced herein as Fig. 15.

The references to cormorant-fishing in Japan previously given, and indeed most of those to follow, are from non-scientific men, but there are now to be set out citations from an ichthyologist of high standing, citations which thoroughly corroborate the popular accounts previously quoted and also those to follow.

Dr. Hugh M. Smith, at that time deputy commissioner of the U. S. Fisheries, visited Japan early in the present century to study her fisheries and related industries. As the representative of the



—*From Pichot after Layrle*

FIG. 14. A LANTERN FROM GIFU SHOWING A FISHING SCENE—PAINTED BY A NATIVE ARTIST.

U. S. Bureau of Fisheries he was made the official guest of the Imperial Japanese Fisheries Bureau and was provided with guides and interpreters who accompanied him on his 5,000 miles of travel. On his return to the United States he published in 1904 and 1905 two papers from which extracts will be made of the cormorant fishing at Gifu.[12]

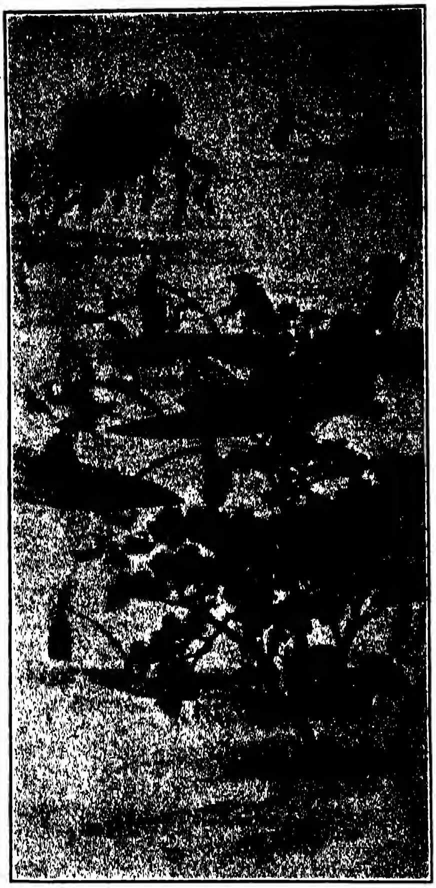
Dr. Smith states that the chief cormorant fisher at Gifu (Fig. 16) was an expert whose ancestors for many generations (for at least 1,000 years and by tradition extended to 2,000 years) had fished at Gifu. His cormorants had a cord around the lower part of the gullet,

[10] Paris, 1903, pp. 27–35.

[11] "Traité de Fauconnerie et d'Autourserie Suivi d'une Étude sur la Pêche au Cormoran." Paris, 1903, p. 243–250.

[12] H. M. Smith, "Japan, the Paramount Fishing Nation," *Transactions American Fisheries Society*, 33rd meeting, pp. 129–132, 4 figures, 1904; "The Fisheries of Japan," *National Geographic Magazine*, 16: 213–214, 3 figures, 1905.

I am also very greatly indebted to Dr. Smith for allowing me to make free choice from his unusual collection of photographs of fishing with the cormorant in Japan.



—*After Belvallette*

FIG. 15. CORMORANT FISHING
AT NIGHT AT GIFU, FROM A NATIVE SKETCH.

and the lines attached to the whalebone piece of the harness (Fig. 17) were fourteen or fifteen feet long. The boats used were of a special kind almost identical with our long narrow dugout canoes, as may be seen in Fig. 18. He notes that there were four men and sixteen cormorants—twelve handled by the head fisherman and four by his assistant. The fishing grounds covered many miles and were divided into sections which were fished nightly—some sections, however, being set aside as imperial fisheries preserves and no promiscuous fishing being allowed, as noted above.

With a blazing fire of pine wood in the iron cresset overhanging the bow of each vessel, the seven boats drifted broadsided down stream, each being kept in line by the two extra men. The fishing —essentially as described above—went on for several hours, each cormorant filling his pouch and throat fifteen or twenty times.

> A spirit of intense enthusiasm fills men and birds alike; and the shouts of the fishermen, the croaking of the birds, the rush of the mountain stream, the splashing and creaking of the paddles, the hissing of the embers as they fall in the water, the weird lights and shadows, combine to make a performance which a westerner is not likely soon to forget.

Dr. Smith was provided with a boat illuminated with lanterns and supplied with refreshments, and from this he witnessed the fishery. Each cormorant boat averaged about 800 fish, and the value of the catch of the seven boats was about $150. The catch was almost entirely *ayu,* the salmonoid fish already referred to.

Next among my notes are those from Ikenoya[13] previously quoted. From him we learn that the Nagara River is seventy to eighty miles long, and navigable for small boats throughout most of its extent, but that the *ugai* (cormorant fishing) is mainly centered around Gifu in three reaches of the river—*kami-ugai, naka-ugai* and *shimo-ugai* (upper, middle and lower cormorant-fishing reaches) plus a fourth section reserved for members of the imperial court. The best fishing is had from the middle of May to the middle of October, at which time the young fish are about three inches long, and the sport is carried on at night over each reach of the river alternately. *Ugai* is best carried on on moonless nights, or before the moon rises or after it sets, since the moonlight drives the fish away—causes them to scatter.

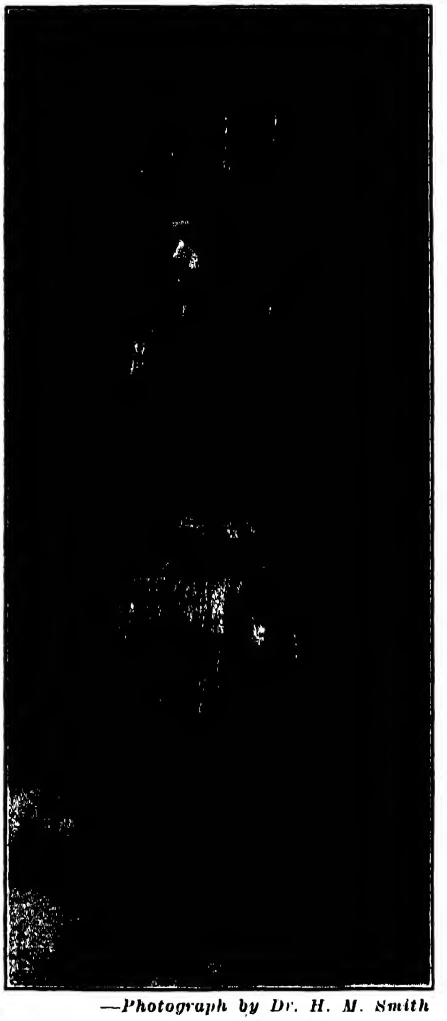
The best fishing boats (Fig. 18) are about forty feet long by three wide amidships—wide enough to contain the

13 S. Ikenoya, "Cormorant Fishing," *Japan Magazine,* May, 1917, pp. 31–32.

bamboo baskets in which the birds are brought by twos to the landing, a basket suspended at either end of a pole. The fishing crew consists of five men—the head fisherman in the bow, two assistants and one boatman in the waist, and the other boatman in the stern. The head fisher looks after the light and handles twelve cormorants, his assistants as learners have four each (making twenty to the boat). The birds have rings around their necks and these must be properly adjusted for each bird. Attached to each ring is a line ten feet long made of cypress bark and held by the fisherman. The birds are encouraged by peculiar cries to dive and catch the fish.

Ikenoya gives an interesting account of how the birds are gotten and trained. They are caught by heavily liming the rocks of their roosting places around Shinoshima in the province of Owari. Good, well-grown cormorants are about two feet in extreme length and weigh about seven pounds each. Their wings are clipped and they are sent blindfolded to Gifu. At first they are very vicious and must be kept tied up. Presently their trainer takes them out on the river every day at noon and allows them (under the leash) to dive, catch and eat one to two pounds of fish each. After about fifteen days of such training and feeding they are taught to catch and disgorge fish. At the end of each daily training period, the birds in regiments of sixteen with three men in charge are allowed the freedom of the river for playing and feeding. While the natural life of the birds is twenty to twenty-five years, under this more or less artificial life they live only about a dozen years.

In 1918, Jihei Hashiguchi published in the *Far Eastern Review* (14: 313–322) an article on the fisheries of Japan with numerous illustrations. Among these is a particularly interesting one (p. 319) labeled "Fishing with Cormorants on the Nagara River, Gifu." The



—*Photograph by Dr. H. M. Smith*

FIG. 16. THE CHIEF CORMORANT TAMER

AT GIFU ABOUT 1903. NOTE HIS PECULIAR DRESS, WHICH IS DESCRIBED FURTHER ON IN THE TEXT.

combination of pale ink and soft paper gives such a poorly printed picture that it will be impossible to reproduce it herein. Moreover there is no reference whatever in the text to this figure.

In 1919 Jabez K. Stone published an interesting article[14] describing a visit to Gifu with a moving picture man, Ben-

14 "Cormorant Fishing at Gifu," *Japan*, 8: 5–7, 44, 5 figures.

—*Photograph by Dr. H. M. Smith*

FIG. 17. NO. 1 CORMORANT

WEARING THE WHALEBONE HARNESS WITH THE ATTACHED LINE, AND STANDING ON HIS CAGE.

jamin Brodsky. Brodsky made a series of films (taken at night) depicting this fishing, and Stone illustrates his article with selections from these. His account is very similar to those already quoted, varying only in slight details. The cormorants are trained to fish in groups of twelve. The body of each bird has around it a cord with a bamboo (not a whalebone) handle to which is attached the line of tough fiber which will not easily tangle or form knots. The birds are well trained, and of hundreds on the river at once, each knows its own boat and master. This latter (*U-jo*) keeps the birds up to their work by calling to them what sounds like "Uish."

In March, 1925, there appeared an account[15] of this fishing at Gifu by Lucy Fletcher Brown. Carrying a letter of introduction from a Japanese priest to a Japanese lawyer in Gifu, she was shown many courtesies and, along with the cormorants was inducted into the fisherman's boat, whence she had an intimate view of the proceedings. However, her account differs but little from the others. There were eight or ten boats, each with four men. The fires were of burning pine knots in cages hung on a pole over the water from the prow of each boat and tended by the cormorant master. The head fisherman expertly handled the reins of "fifteen or more cormorants," while others were shut up in baskets. The *ayu* caught were five to eight inches long, and of these as many as seven were taken at one time from the throat of one bird. There are three illustrations in this article, identical with the first three

15 "Fishing with the Birds [Cormorants] of Gifu," *Japan*, 14: 23-24, 31, 3 figures.

—*Photograph by Dr. H. M. Smith*

FIG 18. A GIFU FISHING BOAT

WITH PROJECTING STEM (WITH CRANE AND CRESSET) AND STERN. AMIDSHIPS ARE FOUR BASKETS CONTAINING CORMORANTS.

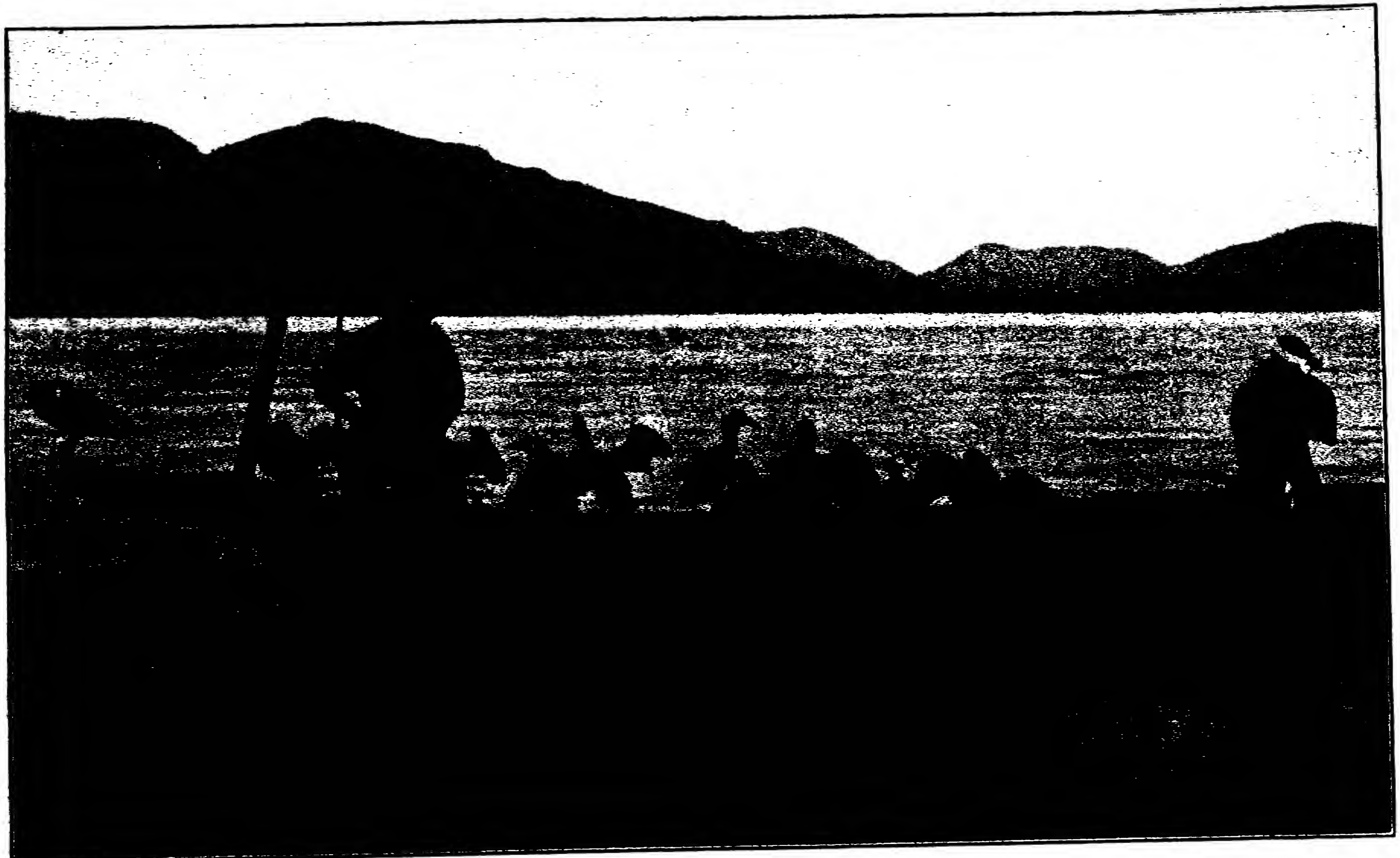
in Stone's account quoted above. This recital, while interesting, adds practically nothing new.

The next account of *ugai* at Gifu is the best of all the popular accounts listed herein. Mrs. May L. Cochrane saw things very clearly and describes what she saw so carefully and effectively that considerable quotation will be made from her spirited story in *Asia*, April, 1925 (pp. 301–305).[16] In general she confirms the others, but in certain details differs. Seven boats fished the river the night she was present. The one she was near (presumably identical with the others) was a long flat-bottomed fishing boat, which was cleverly joined without nails and resembled an Indian dugout [Fig. 18]. The cormorant master stood at the bow, commanding his birds. His understudy worked in the waist of the craft. One of the boatmen stayed near him [the understudy] in the center, and the other one, at his post near the stern, handled an oar.

The birds were harnessed as previously described. There were twenty-four birds in each boat, twelve handled by the master, four by his assistant, and eight held in reserve. Remark is made on the dexterity with which the master handles his twelve reins, and the description of this is worthy of quotation:

I saw that between his fingers he held, divided into groups, a number [twelve] of thin strings, which spread out fanwise from his left hand. With his right he kept sorting and dis-

16 This is done and certain figures are reproduced with the kind permission of the editor of *Asia*.



—*Photograph by courtesy of Gifu Municipal Office*

FIG. 19. THE PROW OF THE BOAT

SHOWING THE CRESSET, THE HEAD FISHERMAN, THE CORMORANTS ARRANGED IN ORDER ON THE GUNWALES—ICHI-BAN PROUDLY STANDING ON THE TIP OF THE BOW—AND THE BOATMAN PUSHING ON AN OAR OR POLE.

entangling these strings with the dexterity of a trained puppet-master. At the other end of his reins a dozen birds were darting hither and thither in intense excitement and apparently hopeless confusion, plunging out of sight beneath the surface, reappearing unexpectedly several yards away, sometimes floating for a brief fraction of time quiescent as toy ducks riding on the tiny waves of a basin of water.

In addition to handling the twelve birds, the leader keeps up the fire and also directs the movement of the boat, but never for one moment does he lose sight of a single bird. Surely he is as Argus-eyed as he is nimble-fingered. It evidently requires years of practice to acquire the requisite skill to be a cormorant master, and the rank of the fisherman is strictly determined by his skill in handling his lines.

The prey is taken in head first by the birds. Trout are easily handled, but long slender-bodied eels can not be tossed in the air and swallowed head first. One young bird held on to his desperately until the fisherman pulled him in and relieved him of his booty. The cord around the neck allows the passage of small fish, but to be sure that the birds have fed well, at the close of the fishing each is "hefted," and those which show up light in weight are fed on the smaller specimens of the catch.

The cormorants are caught in the summer and fall with birdlime spread on rocks around their haunts. The first caught has its eyelids temporarily sewed up to blind it. Seeing it and hearing its cries, others fly to the rocks and are also caught. The old ones are set free, but the young ones are put in baskets and carried to the fishing grounds. Here their eyes are unsewed and the birdlime washed off, but their wings are clipped to prevent their flying away. Next they are taken out in a boat once a day and (tethered with a cord) are taught to swim alongside the boat. If they continue wild and try to bite their captors, their bills are tied up. After a few days (five or six) as they get used to their trainers, all their bonds are removed. Next these "apprentices" are taken out with trained birds to the river. At first the youngsters merely look on and swim about aimlessly while the trained birds fish. After four or five days, however, the young birds begin to imitate their betters and catch a few fish—probably hunger helps much in this learning period. By the opening of the next fishing season (*i.e.*, about May 15) the young birds begin to fish independently and by the end of two years become expert fishermen.

The most experienced cormorant, the one longest in service, is called *Ichi-ban*—"Number One," and as noted above he demands and is accorded special treatment. His place in the boat is nearest the bow or on it (Fig. 19), and here ready to fish, his value to his owner stands at some $75. Each of the younger and lesser birds knows his place also, and if this has been preempted he makes known his wrongs in raucous shoutings. Fig. 19 shows the birds sitting on the gunwale in the order of seniority.

Mrs. Cochrane concludes her interesting account with a very pleasing incident in which is recounted the means by which the cormorant master keeps up the morale as well as the physical health of his feathered helpers. Since this seems to be an essential part of their training, it will be quoted in full. Figs. 20, 21 and 22 will illustrate the account.

Presently one of the cormorant masters loaded his baskets upon a dugout and pushed off. We followed in his wake to a quiet cove, where the boats were beached and the birds liberated for their daily bath. In a bunch they floated over the water, ducking and diving for their breakfast of minnows and other small fry. Ecstasy over freedom and contact with their native element was expressed in hoarse notes and many giddy episodes. The birds flew up just to swoop down and "skid" along on their tails, with webbed feet well up, spread "full sail," before they alighted to swim. Then for an interval they all beat the water madly with great sweeps of their wings, until the air was

—*Photograph by courtesy of Gifu Municipal Office*

FIG. 20. FISHING IS OVER

AND THE CORMORANTS ARE LANDED ON THE BEACH. NOTE THE DRESS OF THE CHIEF CORMORANT TAMER AND THE BUNDLE OF CORDS IN HIS LEFT HAND.

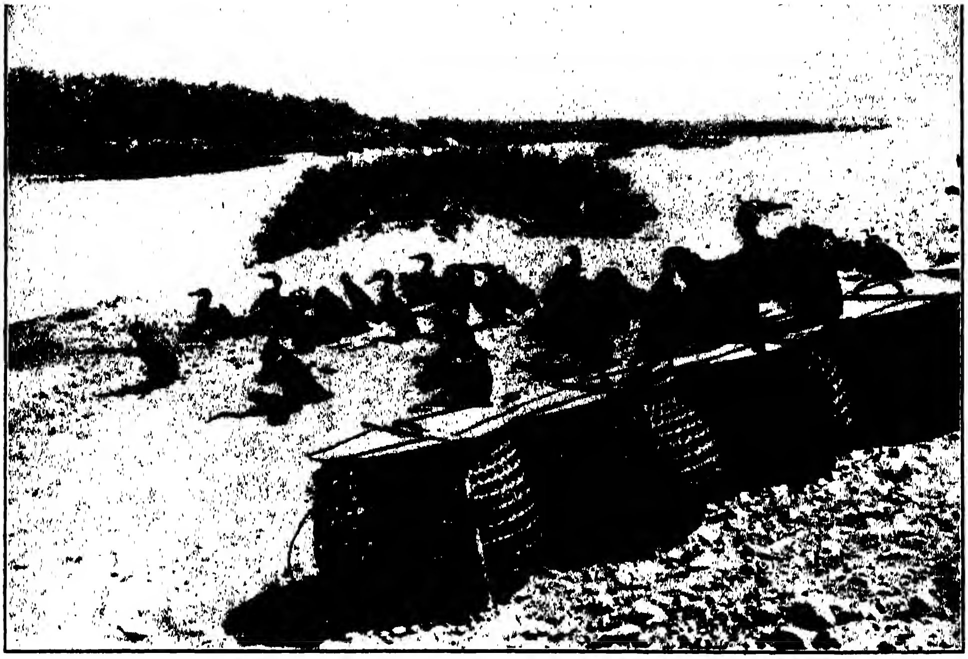
filled with fountain sprays, glittering in the morning sun.

Their surprising antics delighted me for a half hour. Then *Ichi-ban* went ashore, and all the other birds followed. He chose a dry, open space among the bushes, turned his back to the sun, spread his wings and fanned them slowly up and down. Forming in two lines directly behind him, all the others imitated his movements. This solemn rite went on ceaselessly and without a sound for at least ten minutes, until all feathers were dry. When some of the young birds started off on a fresh frolic, they had to be forcibly persuaded by the patient cormorant master to return, but Number One walked quietly to his basket and stood waiting to be lifted into it. Apparently he had put aside the frivolities of turbulent youth and now seemed content to sleep away, or blink away, the sunny hours, with a tranquillity and a peace utterly unknown in his wild state. With the philosophy of old age he had accepted, in exchange for his loss of hazardous freedom, sure food and a basket-home among mankind.

In Fig. 20 is shown the boat with the baskets amidships, an assistant and the chief fisherman with eight cormorants on the beach. In his left hand he holds in a bundle the lines, while his right is free to keep them from becoming entangled—just as Mrs. Cochrane has written. In Figs. 21 and 22, the birds are free on the beach, drying their feathers in the sun.

Dr. Nagamichi Kuroda, by imperial edict, went to Gifu early in the summer of 1926 to study the fishing there. Here he apparently stayed some time, for, instead of describing some particular night's fishing, he wrote a carefully considered general article[17] dealing with the birds and the other apparatus used in the fishery. From his informing article, certain matters confirmatory or contradictory of preceding statements will now be given.

[17] "Cormorant Fishing on the Nagara River," *Japanese Magazine*, Tokyo, 16: 303–320. 16 text figures. 1926.



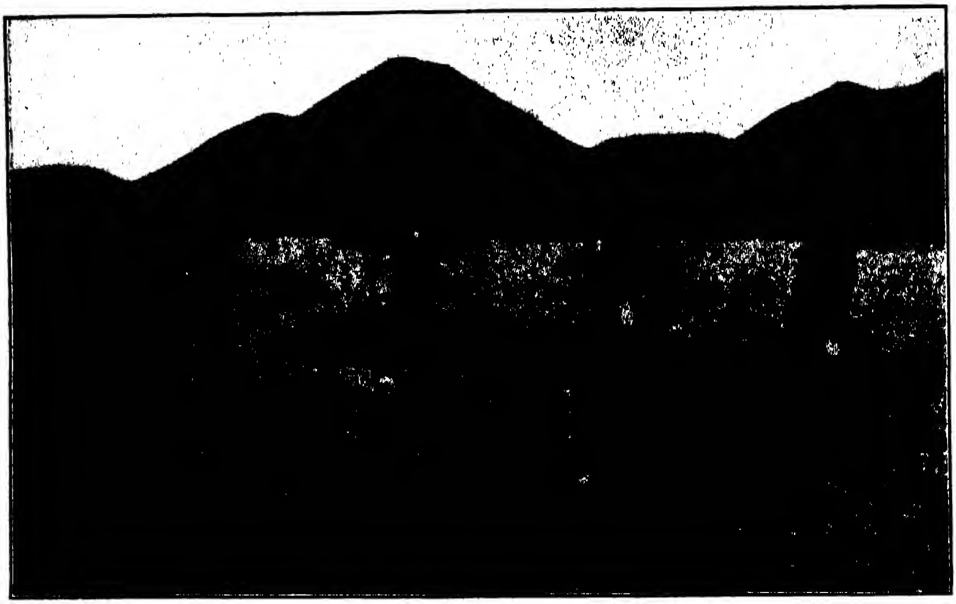
—*Photograph by courtesy of Gifu Municipal Office*

FIG. 21. FISHING CORMORANTS

ON THEIR CAGES AND ON THE BEACH SPREADING THEIR WINGS TO DRY IN THE SUN. THE YOUNGER BIRDS MAKE MUCH ADO OVER THIS, BUT THE OLDER ONES, LED BY ICHI-BAN, BEHAVE VERY SEDATELY.

The cormorants are of two kinds, the larger or Schlegel's cormorant (*Phalocrocorax capillatus* Temminck and Schlegel), which is most used, and also the smaller or Japanese cormorant called *Kawatsu* (*P. carbo hanedae* Kuroda). The latter dwells in trees, the former among rocks. To catch the larger form, the rocks are limed, and on them as a decoy is placed a captive bird with its eyelids sewed up. Birds caught thus sell at 15 *yen* (about $7.50) on the average. When trained they are worth from 150 to 300 *yen* ($75 to $150).

With the eyelids sewed, the birds are carried to their destination. Here the threads are removed, the wing feathers clipped, the birdlime washed off, and the birds tied with hempen cords are put in the water to swim about the boat. At first they are afraid of their trainers, refuse to fish (even for themselves) and often try to bite the men. In this case their bills are tied up and they are left for some time. When somewhat tamed, their bills are freed and they are taken out on a shoal with tame birds to swim about the boats. Presently they begin to follow the example of the trained birds and so take fish for their own food. Since the cormorants are taken during the summer or fall migration, they get several months' training before the opening of the fishing season in the following May. By this time they begin to work independently but still fear the fire and the noises. It generally takes from one to two full years of training to make a good fisher. The trainer studies the psychology of his birds and grades them accordingly. He gives each bird a name and always addresses it by that name. When fishing is to be done, the birds are lined up on the gunwales of the boat in



—*By courtesy of Gifu Municipal Office*

FIG. 22. CORMORANTS ON SHORE

DRYING THEIR FEATHERS AND RESTING IN THE SUN. NEARBY ARE THE BASKETS IN WHICH THEY ARE KEPT WHILE AT HOME OR WHILE BEING TRANSPORTED TO AND FROM THE FISHING GROUNDS.

the order of proficiency, each bird knowing its place. If the birds grow lazy and do not want to fish water is thrown on them to make them do so.

During the fishing season and also during early spring and late fall the keep of the birds presents no problem—they are simply taken out on the river and allowed to catch their own provender. This is called *e-gai* or "feed-keeping fishing." However, the tamers watch the birds, "hefting" them from time to time, and turning up the over-fed to free them of surplus fish, and encouraging the underweighted to catch more—the quantity of food always being estimated by weight. During the winter, the birds are kept in a fowl room next to the trainer's house, and *Ie-gai* or domestic feeding is practiced in time of storms and when snow and ice prevent resort to the river. At all times the birds after being fed at 10 P. M. are put to bed with their throats tied to prevent regurgitation. They "ruminate" until about 10 A. M. next day when their throats are untied and about 1 P. M. they fetch up the bones.

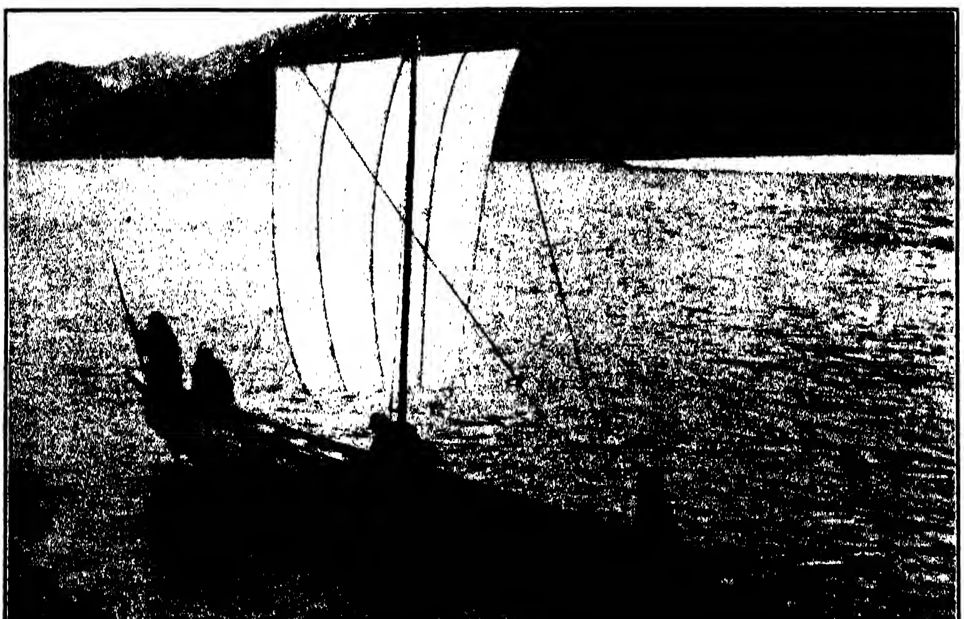
The best birds are four to eight years old, at which time they are worth 150 to 300 *yen*. Older than eight they begin to slow down in their work, though they can be used up to about fifteen years. The birds are brought to the boats in baskets having a central partition of board, with two "intimate" (*i.e.*, friendly) birds in each half (see various figures above). Sometimes these are male and female, sometimes two females, but always friendly birds are put together—non-friendly quarrel loudly. The night baskets have no partitions and contain two friendly birds only.

So much for the birds; now for the other apparatus used. The boats with their curious prows (shown in Fig. 19) are made of pine boards. They last from four to five years. The boats either

drift down stream or are propelled with oars and poles, while sails are sometimes used in going to the fishing grounds as may be seen in Fig. 23. The cords or reins are made of the fine inner bark of the Japanese cypress, and those used in summer are longer than the winter cords. There are baskets for bringing the birds to the boat and for holding them previously, other baskets for holding the fish, and another box-like basket for holding the pine wood and keeping it dry. However, none of these need be described.

The dress of the chief cormorant tamer is very distinctive and is worthy of a brief description. He is easily recognized by his peculiar head-dress, called *Eboshi*. This is made of hemp, is dark blue in color, and sometimes four feet long. It was formerly worn by old-time nobles, but now wound around the head it is a sign that the wearer is an expert cormorant fisher. It also protects his hair from sparks. His body is clothed in a dark blue cotton coat—*Shozoku*. Over this (seen clearly in Fig. 16) is a plastron of blue cotton cloth, a foot wide and one and a half long, to protect against splashing water. Around his waist is a *Koshimino*, or kilt of dried grass, to protect his legs from water and from the wings and claws of the cormorants while he is causing them to disgorge. These things are shown in Fig. 24. Fig. 25 is from a photograph of the chief cormorant fisherman at Gifu in 1927. He is attired in the dress just described.

The fishing is carried on from May 11 to October 15 on every calm night except full moonlight nights or when the river is turbid and the birds can not see



—*Photograph by courtesy of Dr. H. M. Smith.*

FIG. 23. THE FISHING BOATS

ARE GENERALLY ROWED OR POLED TO THE FISHING GROUNDS, BUT IF THE WIND IS FAVORABLE A SAIL IS SOMETIMES HOISTED TO SAVE THE MEN THIS LABOR.

—*Photograph by courtesy of the authorities at Inuyama*

FIG. 24. THE EQUIPMENT OF A CORMORANT FISHER

a, THE *eboshi*; *b*, THE PLASTRON; *c*, THE CORDS FOR TYING THE CORMORANTS; *d*, THE *koshimino*; *e*, THE COAT. THIS IS THE EQUIPMENT USED AT INUYAMA.

the fish. During the first quarter of the moon the fishing is done after moon-set, during the last quarter before moon-rise. Seven boats are used at Nagara-mura and five at Sijiri-mura. Each boat is manned by a *U-jo*, or chief cormorant tamer, stationed in the bow and handling twelve birds. Amidships is his assistant, called *Naka-udzukai*, who fishes with four to six cormorants. In each boat are also two cormorants held in reserve, and any bird not up to standard before or during the fishing is replaced by a reserve fowl. There are two boatmen—the *Ro-nori* in the stern, and the *Chi-nori* in the waist.

The *U-jo* holds the *Ta-nawa*, or hand rope, made of the inner ends of the twelve cords from the cormorants, takes in and empties the full birds (the larger of whom can hold in the throat seventeen or eighteen fish of four to five inches in length), and feeds the fire. The assistant tends his birds and the two boatmen cause the boat to follow the cormorants. Often the boats drifting down stream change places so that the best places may be equally shared.

Cormorant Fishing in the Chikugo and Yabe Rivers at Night from Boats

In Chikugo province, Fukuoka prefecture, in the northern part of the southern large island, Kyushu, Temminck's cormorants are caught by covering their rocky roosts with birdlime in which human hair has been worked to make it more tenacious. This, it should be noted, is a distinct improvement over the method heretofore recorded. The birds are caught mainly by their tails and wings. The first caught are used as decoys for taking others. The fishing on the rivers named is done only at night but from boats slightly smaller than those used on the Nagara. These boats have only two men each as against four or five on the Nagara, one boatman and a cormorant tamer who handles only seven or eight birds contrasted with

twelve at Gifu. The season is the same as on the Nagara. There are ten boats on the Yabe, where the fishing is more thriving than on the Chikugo.

Fishing at Fukuoka City in the Naka and Sawara Rivers at Night and in Daytime by Wading

Here was formerly carried on (abolished about twenty-five years ago) a very unusual kind of cormorant fishing. For knowledge of this we are indebted to Kuroda (1926). Let us hear first what he says of the night fishing.

This fishing was done only on moonless nights. On moonlight nights the fishing was deferred until the next day and carried on in daylight. Each of the fishermen waded, carried a blazing torch, and fished his cormorants from the lower reaches of the river to the upper. Preceding the fishermen and the cormorants were cast-net throwers (*U-saki-uchi*) who caught the frightened fish as they fled upstream. These net-casters were sometimes hurtful to the cormorants, but were generally used, because with their help larger catches were made. The cormorant rope spoken of in the next paragraph naturally could not be used at night.

Kuroda says that the daytime fishing was carried on in the very outskirts of the city itself. Here follows his account.

> Seven or eight cormorant tamers made a group, and went [wading] up the river, handling their cormorants, with one fowl each on his left hand and a hand rope in his right hand. The eight fishermen advance on their way [by wading] abreast, and one of them who stands nearest to the bank and in the deepest place ties a *U-nawa* or cormorant rope (which is a long rope, made of straw) on one of his legs and the other end of this cormorant rope, which

—*Courtesy of Gifu Municipal Office*

FIG. 25. A PHOTOGRAPH OF SUB-LIEUTENANT YAMASHITA

A CHIEF CORMORANT FISHER AT GIFU IN 1927, WEARING THE OFFICIAL DRESS OF HIS OFFICE. HE IS CAUSING A CORMORANT TO DISGORGE ITS CATCH.

—*Photograph by Dr. J. O. Snyder*

FIG. 26. A GROUP OF WADING CORMORANT FISHERS

THESE MEN PLY THEIR TRADE ON THE SHALLOW NON-NAVIGABLE STREAMS. NOTE THE BASKETS FOR HOLDING THE FISH.

crosses the river, is held by a boy on the other side of the river, the shallower part, and dragged by him on his shoulder along the bank. Sweet-fish going down the river are frightened and checked by this rope and forced to run up, turning their direction, which facilitates the cormorants to swallow them. One cast-net thrower or two take their positions ahead of the group of the cormorant tamers. . . . Unless these net throwers are employed the fishing has no success. The *U-jo* carry *Koshi-tebo* or loin baskets about their loins [Fig. 26], and when the fowls have swallowed some ten fishes, large or small, they make them expel the fish into the *Koshi-tebo.*

From this description, the function of the cast-netters is plain as is that of the cormorant rope—which is necessarily not used at night. This last device is, by the way, well known to the South Sea islanders, who utilized it for herding fish in precisely similar fashion. The cormorants used at night are not fed until early next morning, while the daylight fishers are fed immediately the fishing (lasting two to three hours) is over. The birds are fed but once a day and are only employed after they have vomited out the undigested fragments of bone from the preceding meal.

Here then we have an entirely new form of cormorant fishing, boats being dispensed with and the fishermen wading along behind the cormorants. Cast-net fishermen are used as auxiliaries, and in the daytime the fish are herded along by the device of the "cormorant rope." This fishing is of course a purely commercial transaction. Such a group may be seen in Fig. 27.

Cormorant Fishing near Tokyo in the Sagami (Banu), Tama (Rokugo) and Ara (Sumida) Rivers at Night and in the Daytime by Wading

These streams enter into the Atlantic Ocean, and the cormorants used, the

Kawatsu (the smaller or Japanese birds), are caught mainly on the coasts of Tokyo Bay. The fishing, which is carried on both at night and in the daytime, was (so far as I know) first described by Jouy in 1888.[18] He visited the Banugawa (about twenty-five miles from Tokyo) in 1886, and saw this fishing on a moonlight night ("a bad night for fishing"). The river was twenty-five to fifty yards wide and had a swift current. Here follows Jouy's account.

The man with his bird was waiting for us on the stony bed of the river, with his torch of pine-fat burning brightly. The bird (*Phalacrocorax* sp.) was very tame, and sat perched on a rock close by. A cord was tied pretty tightly around the lower part of the throat and between the shoulders, from which was attached a piece of bamboo (having a swivel at each end), long enough to extend beyond the bird's wings and prevent fouling of the cord while the bird was put in the water. The man carried a basket at his side to put the fish in, and a sort of apron in front to hold pine chips for the light. The lantern was a wire cage or basket placed on the end of a long bamboo pole. This, with the cord attached to the bird, which gives him a range of about twenty feet, is held in the left hand, the right being employed in guiding the bird, replenishing the fire and taking the fish.

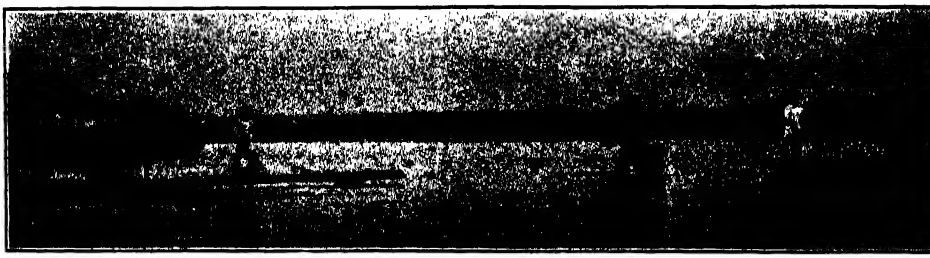
Everything being ready, the fisherman takes the torch in his left hand, and clasping the cord, to which the bird is attached, wades out into the stream, the bird following him and, after performing a hasty toilet, dipping his head and neck in the water and preening himself, begins the business of the night. The fisherman holds the fire directly in front and above the bird's head, so that it can see the fish in the clear water. The bird seems to be perfectly fearless, and as he comes up sparks

[18] P. L. Jouy, "On Cormorant Fishing in Japan," *American Naturalist*, 22: 1-3, 1888.

—*Photograph by Dr. J. O. Snyder*

FIG. 27. FISHING WITH CORMORANTS BY WADING

U-JO, WITH CORMORANTS, AND TWO HANDLERS OF THE NET.



—*Photograph by Dr. J. O. Snyder*

FIG. 28. THE CORMORANT TAMER

STANDS AT (OUTSIDE?) THE NET, THE TWO NETTERS DRAW THE NET IN THE FORM OF A TRIANGLE WITH THE CORMORANT NEAR THE APEX.

of fire are constantly falling on his head and back.

The fishing is done up-stream, the man finding it all he could do to keep pace with the bird as the water surges up nearly to his thighs; in fact, it was hard work for us on shore to scramble along among the rocks in the uncertain light and watch the bird at the same time.

The bird dives, swims under water for eight or ten yards, comes up and is down again, working very rapidly and constantly taking fish. When the fishes are small the bird is allowed to retain two or three in his throat at a time, but a fair-sized fish is immediately taken from him and put into the basket.

During a space of half an hour fifteen fishes were taken, which was pronounced a good catch considering the brightness of the night. The largest of these fishes, which were all of the same species, were nine to ten inches in length, and having been taken immediately from the beak of the bird were scarcely bruised. The largest and best of these we had the next morning for breakfast, the others we gave to our friend, the cormorant, who was kindly assisted by his master to get them past the cord which constricted his throat so that he could not otherwise have swallowed.

The birds are trained especially for the work, and do not fish in the daytime. Our bird was two years old, and was considered a very bright and active fisher, having on good nights, fishing all night, caught as many as four hundred fishes—three hundred was considered a fair night's work. Only calm nights are available, and the darker the better.

That veteran ichthyologist, David Starr Jordan, describes in the following lively fashion daytime fishing with the birds in the Tamagawa or Jewel River, about ten miles east of Tokyo.[19]

At the farmhouse . . . we send for the boy who brings our fishing-tackle.

They come waddling into the yard, the three birds with which we are to do our fishing. Black cormorants they are, each with a white spot behind its eye, and a hoarse voice, come of standing in the water, with which it says *y-eugh* whenever a stranger makes a friendly overture. The cormorants answer to the name of *Ou*, which in Japanese is something like the only word the cormorants can say. The boy puts them in a box together and we set off across the drifted gravel to the Tamagawa. Arrived at the stream, the boy takes the three cormorants out of the box and adjusts their fishing-harness. This consists of a tight ring about the bottom of the neck, of a loop under each wing, and a directing line.

Two other boys take a low net. They drag it down the stream, driving the little fishes—*ayu, zakko, hai* and all the rest—before it. The boy with the cormorants goes in advance. The three birds are eager as pointer dogs, and apparently full of perfect enjoyment. To the right and left they plunge with lightning strokes, each dip bringing up a shining fish. When the bird's neck is full of fishes down to the level of the shoulders, the boy draws him in, grabs him by the leg, and shakes him unceremoniously over a basket until all the fishes have flopped out.

The cormorants watch the sorting of the fish with eager eyes and much repeating of *y-eugh*, the only word they know. The *ayu* are not for them, and some of the kajikas and hazes were prizes of science. But *zakko* (the dace) and *hai* (the minnow) were made for the cormorant. The boy picks out the chubs and minnows and throws them to one bird and then another. Each catches his share "on the fly," swallows it at one gulp, for the ring is off his neck by this time, and then says *y-eugh*, which means that he likes the fun, and when we are ready will be glad to try again. And no doubt they have tried it many times since, for there are

[19] David Starr Jordan, "Fishing for Japanese Samlets [with Cormorants] on the Jewel River," *Outing*, 40: 23–25. Figure. 1902.

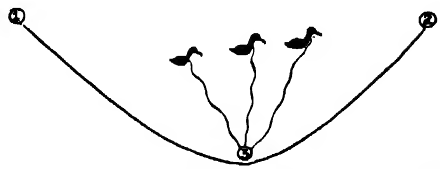
plenty of fishes in the Jewel River, *zakko* and *hai* as well as *ayu.*''[20]

Kuroda (1926), in his authoritative paper previously cited,[17] writes of cormorant fishing in the district in which are found the three rivers referred to above. After noting that fishing in these streams is carried on only in the daytime, he goes on to say that:

. . . one chief cormorant-tamer and two assistants make a group [Fig. 27], but sometimes two chief tamers, two assistant-tamers and one *Haki-kago* (carrier of a basket for sweet-fish caught), form a group. In the former instance the *U-jo* himself carries a *Haki-kago,* and in the latter there is a man specially charged with carrying it with him. The *U-jo* puts his cormorant on his left hand and enters the river, a hand-rope in his right hand, and fishes going upstream, but sometimes he fishes going down the river. [In this case] The fowls are handled so as to swim down the river, following the current of the water.

At the beginning two assistants, who stand at each end of a net with a chief cormorant tamer at the center [Fig. 28] drag the net, long and slender . . . with many weights hanging on its edge and with hand-ropes . . . on both ends. Those two assistants take care that the *U-jo* or chief tamer [standing below the net?] steps on the lower edge of the central part of the net so as not to let it drift away. Within this enclosure the cormorant is immediately set free. The net is stretched so as to form a triangle by the force of the current. The two assistants narrow the net by hauling on both ends from right and left, and go up the river against the current of the stream. On the part of the *U-jo,* he stands at the same spot without moving even an inch until the fishing [in that pool?] is over [Fig. 28]. When the fowl has swallowed many fishes he makes it expel them, by drawing it near to himself, and then immediately lets it free again in the water. This method is repeated several times, and when the two assistants approach the chief tamer the sweet-fish in confusion run up towards the center of the net, swimming against the current of the river, and it is at

[20] This account is republished in Jordan's "Guide to the Study of Fishes," New York, 1905, vol. 2, pp. 116–118. It is referred to in vol. 1, pp. 333–335, and two figures from J. O. Snyder are shown. It is also found in his latest book, "Fishes," New York, 1925, pp. 142–144, Figures 107 and 108.



—*Sketch by Dr. J. O. Snyder*

FIG. 29. DIAGRAM

SHOWING THE NET HELD BY THE TWO NETTERS (1 AND 2), AND THE CORMORANT MASTER (3) WITH THREE BIRDS IN THE ANGLE OF THE NET.

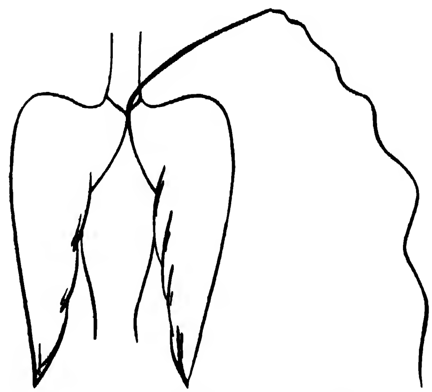
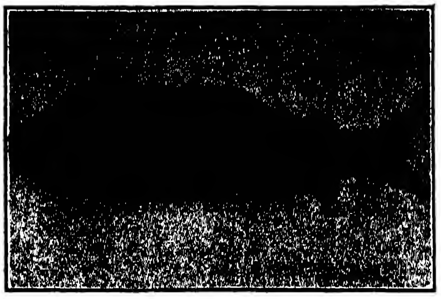


FIG. 30. DIAGRAMMATIC SKETCH

BY DR. J. O. SNYDER TO SHOW HOW THE HARNESS IS FASTENED TO AND AROUND THE CORMORANT'S NECK AND WINGS.



—*Photograph by courtesy of Dr. Kuroda*

FIG. 31. THE SWEET-FISH, THE *AYU* OR *AI*

SHOWING THE MARKS WHERE IT WAS CAUGHT BY THE BEAK OF THE CORMORANT. ITS SCIENTIFIC NAME IS *Plecoglossus* (PLAITED TONGUE) *altivelis* (HIGH SAIL), AND IT IS A MEMBER OF THE FAMILY SALMONIDAE.

this moment that the cormorant can swallow many fish. Thereupon the fishing comes to a close. This mode of fishing can not be applied to a pool which is too deep, it being confined to such a depth as a man can keep standing in.

The distinction between fishing upstream and down, the position of the net with regard to the *U-jo* and the cormorants, whether the birds swim up or down and catch the fishes going against or with the current—all these matters are not very clear, but in any case Kuroda's own words are given. The matter, however, is definitely set out in a communication from Professor J. O. Snyder, who saw this fishing in the Tama River in 1900. His letter with his illustrative diagrams (Figs. 29 and 30) is reproduced herewith with his permission.

In so far as I am able to recall, the practice of fishing with cormorants is carried on in only a few localities in Japan—I know only of Lake Biwa, the Nagarakawa province of Mino, and on the Tamagawa, which is within easy reach of Tokyo. The pictures [Figs. 26, 27, 28] were made at the Tamagawa in 1900. At Lake Biwa and the Nagarakawa (Nagara River) fishing is done at night with torches; at the Tamagawa (Tama River) it is done by daylight. At the latter place the fishermen wade in the stream, driving the fish by means of a fine-meshed net with leads on the lower edge and floats above. The net is drawn seine-fashion, a fisherman at either end [Fig. 29], while the man who manages the birds wades near the middle of the net, which drags against his legs. The birds work back and forth within the angle of the net. Each bird is held by a leash, a long line made of fiber from the bark of a tree, the *Hinoki*. This leash is attached in turn to a strip of whalebone about one foot long. This serves to keep the leash from entangling the wings or legs of the bird. The whalebone is attached to a harness or hempen cord, one strand passing around the neck, and one backwards and around each wing, meeting in front. The neck strand may be tightened to constrict the pouch. This harness is used at both the Nagarakawa and Tamagawa fisheries [Fig. 30].

I believe that cormorant fishing is a sporting, rather than a commercial affair. At the Nagarakawa the fishermen may be engaged along with a sort of houseboat where meals are served, the little *Ayu* furnishing a most delicious dish. Music, geisha girls and various decorations often lend a festive air to the occasion.

With this very pertinent first-hand description, I close the accounts of "Cormorant Fishing in Japan."

ASPECTS OF NUTRITION AND METABOLISM IN CHINA

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This report is an attempt to summarize the present state of knowledge on the nutrition and metabolism of the Chinese. China presents the interesting situation of a people who have lived in almost complete isolation, whose dietary habits therefore must represent definite responses to definitely local stimuli or racial traits. And the length of time involved has brought China more nearly to a state of economic and nutritional equilibrium than can ordinarily be attained. The adjustments which the human mechanism has made to these influences present interesting topics of study. Moreover, the Chinese people are sufficiently numerous and homogeneous that a reliable biochemical average is easily possible.

Some of those who first came in contact with China's nutrition problem expected to find a mechanism which not only operated on an entirely different intake level, but which also involved fundamental differences in the metabolic process such as might characterize a distinct species. In this direction there has been disappointment. The first studies, begun a little over ten years ago, were concerned with a systematic examination of food materials and their analysis. It was shown that the food materials of the Orient were quite similar to those of the Occident, apart from one or two items such as the soy-bean which China had been led by her economic situation to exploit to a peculiar degree.

Certain characteristics of the food intake are shown in the accompanying Tables I to III. The division into North China and South China is a well-recognized one. Climate, habits of life and agricultural conditions differ greatly in these two areas. The figures for North China are averaged from the diets of about 1,500 individuals from middle-class families, the dietary records for each individual or family extending over periods of several weeks or more. Some of these data were gathered by the author in the Chee-loo University laboratory; the remainder include those reported by Wu and Wu[1] in Peking. The

TABLE I. CHINESE DIETARIES.

COMPOSITION IN PERCENTAGES BY WEIGHT

	North China	South China	United States
Cereals	57.0	59.7	25
Legumes	7.8	18.2	
Vegetables and fruits	27.1	21.0	20
Sugar and starch	0.2	0	14
Fats and oils	0.8	1.1	
Meat and fish	3.9	0	18
Eggs	0.5	0	5
Milk and cheese	0	0	15
Other foods	2.7	0	3

TABLE II. CHINESE DIETARIES.

INTAKE OF TOTAL FOOD, PROTEIN, FAT, CARBOHYDRATE AND CALORIES PER MAN PER DAY

	North China	South China	United States
Total food (gms)	1188.0	1303.0	
Total protein (gms)	86.4	67.1	106.0
Total fat (gms)	34.1	27.2	
Total carb. (gms)	537.0	604.9	
Total Calories	2794.0	3008.0	3256.0
Calcium (gms)	0.337		0.740
Phosphorus (gms)	1.178		1.630
Iron (gms)	0.0187		0.0179
Average weight of man (kilos)	60.0	54.0	70.0

[1] H. Wu and D. Y. Wu, *Chin. J. Physiol. Rep. Ser.* 1: 135, 1928.

TABLE III. CHINESE DIETARIES.

PERCENTAGE DISTRIBUTION OF PROTEIN AND ENERGY AMONG DIFFERENT GROUPS OF FOOD MATERIALS

	North China		South China		United States	
	Pr.	En.	Pr.	En.	Pr.	En.
Cereals	75.2	83.3	84.2	91.9	37.3	38.2
Legumes	10.6	3.9	6.8	1.2	10.5	12.1
Vegetables and fruits	4.5	2.9	9.0	2.8		
Sugar and starch	....	0.5	...	0	0.1	10.1
Fats and oils	....	3.5	....	4.1	0.3	10.3
Meat and fish	8.1	4.8	0	0	35.3	19.0
Eggs	0.8	0.2	0	0	4.6	1.8
Milk and cheese	0	0	0	0	11.6	8.1
Other foods	0.8	0.9	0	0	0.3	0.4

figures for the American diet are taken from Sherman.[2] The data for South China are reported by Powell,[3] and are for day-laborers; the day-laborer represents an extreme rather than a middle-class average. The most outstanding feature of these tables is the high consumption of cereals (wheat bread in North China and steamed rice in South China), the absence of dairy products, the small amount of meat consumed and the low values for total protein.

Observations reported elsewhere[4] on Chinese dietary habits show how greens, raw vegetables, sprouted soy-beans, short-time cooking, are some of the qualitative devices which blind experimentation has led the Chinese to employ to supply vitamines and similar essentials. Certain districts have reverted to a mixture of cereals rather than depend on a single vegetable protein, apparently with profit. Abundance of roughage is characteristic of the dietary; constipation and the use of pills are almost unknown.

The value for protein though low is in effect still lower when it is remembered that the oriental diet is a very bulky diet and that the coefficient of digestibility of protein is lowered accordingly. Atwater, quoted by Sherman,[2] gives 92 per cent. as the degree of digestibility for protein in the ordinary American mixed diet. Oshima[5] finds 78 per cent. for the more bulky vegetarian diet, while McCay,[6] studying the bulky rice diets of India, shows that a consumption of 766 grams of rice (dry weight) per day will lower this coefficient to 52 per cent. The South China diet here reported is such a rice diet; in other words, 67.1 grams of ingested protein per day becomes an effective 35 grams per day! No experimental data on the coefficient of digestibility of protein in the Chinese vegetarian diets have as yet been reported. We are hoping to secure such data.

There has been too great a tendency on the part of the China enthusiast to extol rather than sanely to evaluate. It is commonly asserted that the mass of the Chinese people live just on the fringe of starvation, or just within the fringe of an animal existence. This is true, and while it is interesting to note how China by a sort of blind experimentation has selected just those food materials which under prevailing economic conditions most effectively meet nutritive needs, the Chinese people have been too often complimented on their ability to thrive on this fringe of existence. Attention has been called to the tall, apparently robust physique of Shantung, and the world traveler reminds us of limitless capacity for toil and labor, but the fact remains that the mass of the people are dangerously underfed. Nutritional science today is interested in the optimum metab-

[2] H. C. Sherman, "Chemistry of Food and Nutrition," 1926.

[3] M. N. Powell, *Chin. J. Physiol. Rep. Ser.* 1: 129, 1928.

[4] W. H. Adolph, *Amer. Food J.*, 20: 441, 1925.

[5] K. Oshima, "Japanese Investigations on Nutrition of Man," 1905.

[6] D. McCay, "The Protein Element in Nutrition," 1912.

olism, not in mere existence, and the problem before the Chinese people is one of improved growth and vigor rather than mere maintenance of equilibrium.

Famines in China show definitely that the Chinese diet allows no emergency reserve, for a slight lowering of the quality and quantity of food intake produces immediate disaster. Careful observations on athletic squads, school kitchens and hospital groups have shown how intimate is the relationship between food intake and health. Overwork among students manifests itself, not as nervous breakdown, but as tuberculosis. One director of a large nursing school found that she could reduce the annual tuberculosis casualties among her student nurses either by improving the food, or by reducing the number of hours of work per day. Either method was equally effective. Wu and Wu[1] have fed typical Chinese and typical American diets to laboratory rats and have demonstrated the superior growth-promoting properties of the latter type of diet.

Famines in China have furnished excellent opportunities for observing dietary requirements. In the famine of 1921, one of the relief commissions set out definitely to determine the minimum amount of food for a living diet. It was determined that a daily ration of ten ounces of mixed cereal and soy-bean plus four ounces of vegetable and a small amount of salt, yielding a total of 1,200 Calories, would support a man if he did no work. Seventeen men were sustained on this diet for ten weeks, weighings being taken every few days. The report is that the men seemed quite content on this diet and looked well. Others on the same diet but who worked during this period lost heavily and had to receive a double ration. These data then were used as the basis for a relief ration for some tens of thousands of people. Such data almost approach the conditions of a basal metabolism test. In this same famine the American Red Cross employed an average of 20,000 men in road construction work for seven months; they were placed on a well-balanced diet furnishing about 2,800 Calories, the diet being composed essentially of mixed cereals with fresh vegetables.[7] At the same time in an adjoining area a similar group were fed a similar cereal ration without the fresh vegetable admixture. The second group were observed to be lacking in energy; their general health was poor, and they became an easy prey to contagious disease. These data were as convincing as any present-day experiments on laboratory rats, and in addition the experiment involved a large number of individuals. Lack of transportation in China, as well as the existence of natural division lines, means that it is possible to set off large areas for experimental purposes, and in times of famine thousands of people become available *en masse* as experimental subjects.

The tables presented show a very small meat intake. Table IV indicates

TABLE IV

MEAT CONSUMPTION OF THE PRINCIPAL COUNTRIES OF THE WORLD (GRAMS PER CAPITA PER DAY)

United States	149
Great Britain	130
France	92
Belgium and Holland	86
Austria-Hungary	79
Russia	59
Spain	61
Italy	29
Japan	25
China (North)	15

the place which meat occupies in the diets of the nations. The figure for China is estimated from trade reports; data for the other countries are those quoted by Robertson.[8] The importance

[7] H. C. Embrey, *Am. J. Publ. Health,* 12: 514, 1922.

[8] T. B. Robertson, "Principles of Biochemistry," 1924.

of meat may still be a moot point, but the experience of the Chinese people would seem to confirm the thought that a vegetarian diet is at least not impossible. Their present food habits have certainly not been greatly altered for at least 1,500 years, and possibly not for 3,000 years. There is no room here for philosophizing on the place of meat in the diet. One who has been in contact with the nutrition problem in the Orient willingly subscribes to the observation that meat diet seems to be characteristic of the most aggressive peoples of the world.

The figure for calcium (Table II) is low. The amount may not be low enough to cause disease, but like many of the other dietary factors it seems to be just low enough to prevent optimum growth. Public health authorities report the following as the common diseases of China: tuberculosis, beri-beri, xerophthalmia, rickets and osteomalacia, while those infrequent are: appendicitis, gastric ulcer, gout, rheumatism, gallstone and obesity. Note that most of these are recognized as nutritional disturbances.

Interest in the basal metabolism of the oriental peoples was stimulated by an experiment on a few Chinese women students in an American institution which showed a lower basal metabolic rate.[9] Takahira[10] in Japan had concluded that the basal metabolism of Japanese and Americans is essentially the same. Data gathered by Earle[11] for China, as yet incomplete, indicate that the basal metabolism for the Chinese may be slightly lower. Ling,[12] studying blood constituents, finds that the mean for North China exhibits only very slight differences from the normals for Americans. The blood pressure of Chinese would seem to be lower than the normal in the United States.[13] The Chinese as a rule excrete less chlorine than Westerners.[14] Metabolism studies show that higher amounts of creatinine and uric acid are excreted;[15] the higher excretion of uric acid may be related to the tea habit, while in South China at least the amount of ammonia nitrogen excreted is exceptionally high.[16] But South China is really subtropical, and the whole subject of metabolism in the tropics is still unsolved. Among the most interesting data being collected are those which show how the blood pressure of the American moving his residence from the United States to North China approaches the lower Chinese norm.[13] The basal metabolism for Westerners in South China[11] is apparently lower than the recognized American and European standards.

Dietary and metabolic habits must be either inherited or environmental. While many data still remain to be gathered, evidence so far points to environmental factors as the influential ones. South China and North China present distinct types of climate, and when the southern Chinese emigrates to North China and finally adopts the food habits of North China, which incidentally he does with reluctance, his sons begin to approach in stature and weight the larger standards of North China.[17] Studies on the Japanese who have emigrated to the United States[18] show that

[9] G. MacLeod, E. E. Crofts, F. G. Benedict, *Am. J. Physiol.*, 73: 444, 1925.

[10] H. Takahira, "Progress of the Science of Nutrition in Japan," p. 11, 1926.

[11] H. G. Earle, *Chin. J. Physiol. Rep. Ser.* 1: 59, 1928.

[12] S. M. Ling, *Chin. J. Physiol. Rep. Ser.* 1: 119, 1928.

[13] C. L. Tung, *Chin. J. Physiol. Rep. Ser.* 1: 93, 1928.

[14] B. E. Read and S. Y. Wong, *Phil. J. Sc.*, 22: 127, 1923.

[15] S. Y. Wong, *Chin. J. Physiol. Rep. Ser.* 1: 123, 1928.

[16] J. A. Campbell, *Bioch. J.*, 13: 239, 1919.

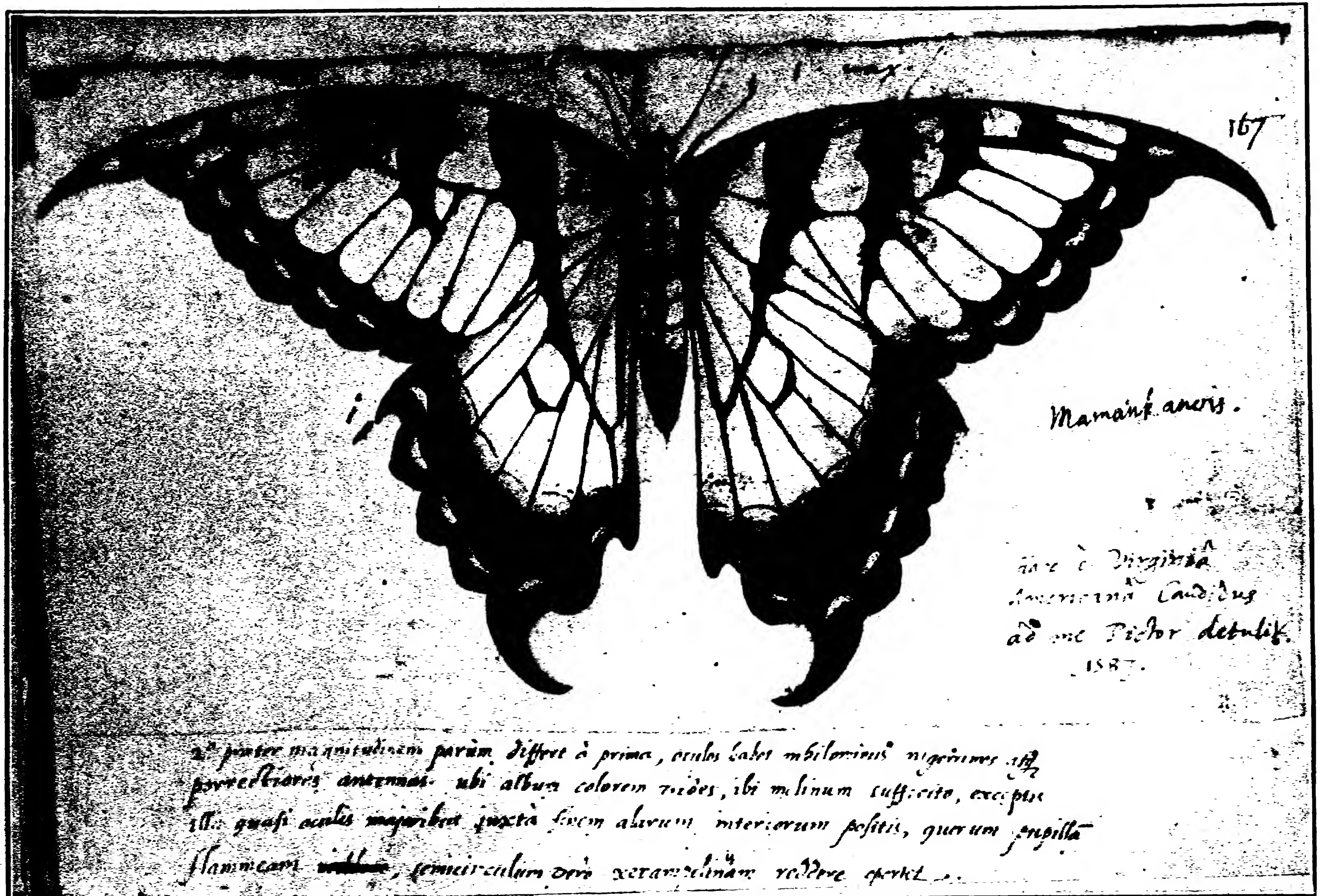
[17] H. Necheles, *Chin. J. Physiol. Rep. Ser.* 1: 80, 1928.

[18] K. Kanzaka, *Annals Am. Acad. Pol. Soc. Sci.*, 83: 88, 1921.

the new environment of food and climate is producing a larger physique. Southern Chinese who emigrated to Hawaii are found to have attained a greater average height after several generations in the new environment.[19] There seems to be general agreement that the different races which make up the population of the United States now metabolize on the same plane, and that so-called racial metabolic traits, if there were any, have quite disappeared. There may even be an inherited racial difference between the northern Chinese and the southern Chinese, but it would appear to have no influence on the metabolism of the organism equal to that of climatic environment and dietary habits.

In conclusion, dietary studies in China indicate wide-spread conditions of undernutrition. Climate and environment in turn seem to have produced a temperament which accommodated itself to a low protein consumption and to a lowered metabolism generally. A type of blind experimentation has aided the Chinese people in reaching probably the best solution of a bad situation.

[19] V. B. Appleton, *China Med. J.*, 40: 259, 1926.



167
Mamankaneis.
ã Virginia Americanus Candidus ad me Pictor detulit.
1587.
2a pariter magnitudinem parum differt à prima, oculos habet nihilominus nigriores atque
porrectiores antennas. ubi album colorem vides, ibi melinum sufficito, exceptis
illis quasi oculis majoribus juxta finem alarum interiorum positis, quorum pupillam
flammeam, semicirculum verò xerampelinum reddere oportet.

THE FIRST PICTURE OF AN AMERICAN BUTTERFLY

By Dr. W. J. HOLLAND

CARNEGIE MUSEUM, PITTSBURGH, PENNSYLVANIA

On the plate we give a photographic reproduction of the very first drawing of an American butterfly made by the hands of man. It fortunately still exists in the library of the British Museum in Bloomsbury, London. To the trustees of that library I am indebted through the kind intervention of my friend, Captain N. D. Riley, of the Natural History Museum in South Kensington, for the privilege of being able to reproduce it.

While the picture itself possesses great interest, the inscriptions on the right side of the plate are even more interesting. These have never before been published. The lower inscription is as follows:

Hanc è Virginia Americana Candidus ad me Pictor detulit, 1587.

Literally translated it is, "Candidus, the Painter, brought this to me from American Virginia, 1587." The demonstrative pronoun "hanc" being feminine, the ellipsis must be that of a feminine noun. This might be "rem" = *thing*, or "picturam" = *picture*. If the writer had used the masculine "hunc," it might mean "papilionem" = *butterfly;* if he had used the neuter "hoc" it might mean "specimen." The use of the feminine, taken in conjunction with the use of the word *"Pictor,"* leaves no doubt that the writer of the inscription meant to designate the very *picture*, or identical *thing*, upon which he was writing, as having been brought to him from "American Virginia" in 1587.

The word "Candidus," given as the name of the donor, is good Latin for *White*. The inscription thus rendered reads: "White, the painter, brought this picture to me from American Virginia, 1587." Thereby hangs a tale.

The inscription recalls the story of the first attempt made by Englishmen to establish a colony in the New World.

Sir Walter Raleigh, having received from Queen Elizabeth a patent for colonization, sent out Philip Amidas and Arthur Barlowe in 1584 to seek a suitable place at which to locate a colony. They soon returned with a glowing account of what is now the coast of North Carolina. At that time the whole Atlantic coast of North America north of Florida was called Virginia in honor of "The Virgin Queen." In fact, some of the early writers speak of "the continent Virginia." On June 9, 1585, one hundred and eight colonists under Ralph Lane sailed from Plymouth in seven small vessels. The commander of the fleet was Sir Richard Grenville. The colony was landed at the north end of Roanoke Island on August 17. A week later Grenville sailed on his return to England. In the following year on June 19 the colony, half starved and in fear of their lives from hostile Indians, sailed for England in the fleet of Sir Francis Drake, which had appeared at Roanoke. Only a few days after these first colonists had set sail on their return Sir Richard Grenville again arrived at the spot with provisions and more colonists. Only fifteen of those whom Grenville brought out on this second expedition consented to remain. Grenville again returned to England. Raleigh resolved to send a third body of colonists. John

Fiske in his "Old Virginia and Her Neighbors," relating the story of this adventure, says: "John White, a man deft with water-colours, who had been the artist of Lane's expedition, was their governor." With White went his daughter and her husband, Ananias Dare, who helped in the care of the party. They arrived at Roanoke Island on July 22, 1587, and were forced to remain there, for the sailors refused to go to the Chesapeake, whither they had intended to remove the colony. Not a trace of the fifteen colonists who had been left the year before could be found. On August 18 White's daughter Eleanor, Mrs. Dare, presented her husband with a baby daughter, the first child of English parentage born in the New World. On August 20 the child was baptized Virginia Dare. White not long after returned to England for supplies for the colony, but when he came back the next year the company of over one hundred persons whom he had left behind had vanished, and all that could be discovered was the word "CROATAN" carved on a tree. From this it was inferred that they had gone away with Indians of that name, among whom in later years were found people of apparently mixed blood, bearing English names, who were thought to be descendants of the "lost colony."

Among those "lost" in the piny woods about Hatteras were White's daughter, Eleanor, her husband, Ananias, and their baby daughter, Virginia Dare. It must have been with a heavy heart that White, bereft of daughter and grandchild, again set sail to return to England.

There seems to be no doubt that the picture was painted by John White, the commander of Sir Walter Raleigh's third expedition to "Virginia" in the year 1587. It represents (in impressionistic style) the male Tiger Swallowtail, one of the common butterflies of the Carolinas, *Papilio turnus* Linn., the dimorphic female of which is *Papilio glaucus* Linn.

But there is another inscription on the original drawing in a different hand from that which we have been considering, and written with different ink. It is "*Mamank anois.*" What does it mean? I think it is the Indian name of the insect.[1] We can fancy White, "deft in the use of water-colors," receiving the butterfly from the hands of an Indian lad, seating himself with a scrap of paper, rapidly painting the picture and interrogating the boy for its name, which White scribbled upon the margin of his sketch.

But now another question arises. Who was the man who wrote the words: "*Hanc è Virginia Americana Candidus ad me Pictor detulit, 1587*"? Who was "me"?

A wood-cut of the original painting first appeared in that curious and now very rare old book: "Insectorum sive Minimorum Animalium Theatrum." The authorship of this book is exceedingly composite and a long time elapsed between its inception and its final publication. The subtitle of the book is as follows:

Olim ab
EDOARDO WOTTONO.
CONRADO GESNERO.
THOMAQUE PENNIO.
inchoatum:
Tandem
THO. MOVFETI *Londinati opera sumptibusq. maximis concinnatum,*
auctum, perfectum;
Et ad vivum expressis Iconibus supra quingentis illustratum.[2]

[1] Since the writing of the above, Mr. M. W. Sterling, chief of the American Bureau of Ethnology, has kindly called my attention to the fact that in the Vocabulary contained in Strachey's "Historie of Travaile into Virginia Britannia, etc., 2," the expression "manaanggwas" is given as the Indian equivalent of the word *butterfly*. My suspicion is thus confirmed.

Below this comes the famous picture of the beehive, the trade-mark of the printer, Thomas Cotes, familiar to all Shakespearian students, for Thomas Cotes about this time was printing the second folio of Shakespeare, which has on its title-page the same beehive shown on the title-page of the work of which we are speaking, but not surrounded, as in the "Insectorum Theatrum," by figures of bugs, butterflies, spiders and millipedes. At the foot of the title-page are the words:

Londini ex Officina typographica
Thom. Cotes.
Et venales extant apud
Benjamin. Allen
in diverticulo, quod Anglice dicitur,
Popes-head Alley,
1634.[3]

Sir Edward Wotton stood high in the English diplomatic service. In 1586 he was sent to France to explain to Henri IV the intrigues of Mary, Queen of Scots, against Queen Elizabeth; and afterwards in 1610 he was ambassador extraordinary to France. He held many offices and died in 1626. He was deeply interested in entomology. Conrad Gesner died in December, 1565. He was for his day a great naturalist and the author of some of the earliest writings on natural history published in western Europe. He was a close friend of Dr. Thomas Penny. Penny was with Gesner on the continent when he died, and after his death helped to arrange Gesner's collections.

Penny was a physician of great repute and so was his friend Thomas Moffett, Mouffet or Muffet. Both had graduated at Cambridge; both had studied medicine on the continent; both were court physicians; both were botanists and entomologists. They collaborated for years. The interesting old book concerning which I am writing was begun by Penny and Gesner working together in Germany. Sir Edward Wotton lent a helping hand. When Dr. Penny died his friend and colleague, Moffet, took up the unfinished work, which he arranged and completed. In 1590 he dedicated it by royal permission to Queen Elizabeth and received official sanction to print it at The Hague. But delays followed. When James I of England came to the throne in 1603, Dr. Moffett changed the dedication to the king. At Moffett's death in 1604 the manuscript with its illustrations, pasted in where they were to appear, came into the hands of Darnell, Moffett's apothecary. Darnell sold the manuscript to Sir Theodore Turquat de Mayerne, Baron Albone, court physician in the time of Charles I. Baron Albone published the book at his own expense in 1634, dedicating it to Sir William Paddy, and in his dedication speaks of Moffett as "an eminent ornament of the Society of Physicians, a man of the more polite and solid learning, and renowned in most branches of science."

This in brief is the story of the book in which our picture first appeared on page 98, as a wood-cut, faithfully reproducing the original drawing. But who was the man who received the drawing from John White, and recorded the fact on its margin? It can not have been Gesner. He had died, as already stated, in 1565. I doubt that Dr. Moffett wrote the inscription upon the original drawing, for the handwriting is distinctly different from that of the body of the manuscript written by Moffett's pen. This leaves only two others of the joint authors to be considered. Dr. Penny

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[2] *Translation*: Begun long ago by Edward Wotton, Conrad Gesner and Thomas Penny; finally prepared, enlarged and perfected by the labor and very great expense of Thomas Moufet, born in London, and illustrated by over five hundred figures drawn to life.

[3] *Translation:* From the printing office in London of Thom. Cotes, for sale by Benjamin. Allen in the lane which in English is called Popes Head Alley, 1634.

died in 1589. Sir Edward Wotton stood high at the English court. He was the friend of Sir Francis Drake and of Sir Walter Raleigh. He was very likely to have been brought into contact with John White, when the latter returned to report to Raleigh what he had done. I am not able to decide the question, but I am strongly inclined to think that the author of the inscription was Sir Edward Wotton, who gave it to Dr. Moffett, who pasted it into the manuscript where it to-day remains. Some student of chirography delving among the old papers in the British Museum may be able to settle the question. The original manuscript is preserved in the British Museum in the Sloane Collection (No. 4014). It carries both the dedication to Queen Elizabeth and to James I.

What is clear is that the first picture of an American butterfly was painted by John White, the leader of Sir Walter Raleigh's third expedition to Roanoke, in the year 1587, less than one hundred years after Columbus had made his first landfall in the New World, twenty years before Captain John Smith and his associates reached Virginia and thirty-three years before the Pilgrim fathers disembarked at Plymouth. The artist was the grandfather of the first white child of English parentage born on the continent of North America, Virginia Dare.

TWENTY-FIVE CENTURIES BEFORE CHARLES DARWIN

By TZE TUAN CHEN

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MANY books and articles have been written on Chinese superstitions and myths concerning the origin of life and living things, but, so far as the writer is aware, the deeper theories formulated by some ancient Chinese thinkers and the similarities between these theories and those held by Greek philosophers and scientists have been but lightly touched upon. This paper attempts to call attention to the fact that some ideas of the origin of the species, of variation, of adaptation and of the structure-function theory were formulated several thousand years before Darwinism came into existence and have all been neglected by Western writers in their history of the theory of organic evolution. It must be remembered that, however ambiguous these theories are, they were first expressed several thousand years ago.

One of the most curious aspects in the history of human thought so far as literature and science have revealed it to us is the strange interest taken in discussing the problem of evolution, which had two aspects: the origin of life and the origin of the forms of life. Ever since men were able to think it has been an open question as to the origin of things which they see around them. Even primitive people seem to have attempted to speculate on the causes of the origin of the universe and the evolution of life.

What is the alpha and omega of the universe? Whence came life? How did being become beings? Why have things been as they were? These are some of the eternal, metaphysical as well as scientific, problems which thinking men of all ages and of all countries, with all their limited information and all their intelligence and energy, within their brief spans of time, have endeavored to solve in one way or other as seemed satisfactory to them. Some have thought of all the wonders of life as the work of God; some ascribed it to the Logos; some named it the unknowable, while some others called it evolution.

While we credit the theory of evolution to modern Western thinkers, we are apt to forget the philosophers of the Orient who formulated almost the whole theory without knowing its significance. It is with this point in view that the writer will proceed to discuss in the following paragraphs this subject of evolution by indicating its position in Chinese myths and folk-lore and then attempt to give an account of some deeper theories as stated by some ancient Chinese philosophers.

EVOLUTION VIEWED THROUGH THE CHINESE FOLK-LORE AND MYTHS

There is a very popular myth in regard to the origin of life which is connected with the name of Pan-ku. He was considered the first living being on the earth, and he had the task, as the story goes, of chiseling and molding the world into its existing shape. He is pictured as a giant with a mallet and a chisel in his hands. It took him 18,000 years to complete his task. The work of Pan-ku was first devoted to the separation of the earth from heaven, and then to the giving of life to the earth which he had so industriously made. Hence he was the creator of our planet.

A second myth involves the name of Nu-ho-shih, supposed to be a goddess of great ability. She tried to make the

earth adaptable to living things, and her task was to patch the heaven which had been broken. Through long, hard work she succeeded in selecting and polishing certain stones by means of which the cracks of the broken heaven were patched.

In "Si-yu-chih," a very popular mythical story, we read about a queer stone which, exposed to the natural changes and tests and receiving some dynamic and vital elements from the sun, moon and stars, came to pass into life as a very intelligent monkey. Later, this monkey, owing to its superior intelligence and ability, was endowed with personality.

Another interesting myth explains that living things have their origin in a peculiar gas possessed by a powerful god. This god, having proved to be weaker than another god against whom he was warring, evolved a gas in which various fierce animals were present, and thus defeated his enemy. These freed, animals then came to live in the world.

Still another myth states that man was evolved from a broom. One day the broom was dropped from the heavenly paradise to the earth and there it remained for thousands of years. Becoming animated and possessing the abilities of walking and eating, it eventually became a man from whom men are descended. Some uneducated persons believe that men in ancient times did not die, but changed every hundred years by "molting."

Certain speculations are interesting. One country saying that life came with wind is based upon the idea that as wind swept over the earth it changed non-living things into living beings. This reminds us of the speculation of ancient Anixemenes that air imparts life to all things.

Another bit of folk-lore bears some familiarity to the so-called planetesimal theory of Chamberlain. Country folk often say that living things first came to the earth from the moon. Their reason is based upon an assumption that the black spots they see in the moon are a monkey pounding rice, a snake winding its body around a pine tree, and so forth.

Some are fooled by inaccurate observations and superstitious traditions. They realize and recognize changes in things, but they give the wrong data. For instance, many still believe that a sparrow can change to a clam when it is dropped into the sea; that a shark will change to a tiger when it gets on land; that a fox possesses wonderful powers of transformation; that a rat can change to a bat; that fireflies come from cow-manure; that a wasp can make caterpillars his adopted sons and change their whole appearance; that a big snake can change to a dragon which later on will fly up to the sky. These traditional views, in spite of their fallacies, indicate the belief in change from one type of animal to another type.

So much for mythological stories. Let us now proceed to investigate what the ancient thinkers have said about evolution.

Origin of Life

In regard to the origin of life, Lao-tze (born 604 B. C.) tended to explain it philosophically. He said, "Everything comes from something, something comes from nothing." This assertion bears some familiarity to the theory of Squarez, who believed that the *materia prima* was made out of nothing.

Some philosophers had the idea that in the beginning of the world there existed five "elements": gold, wood, water, fire and soil. Through the positive and negative action of these "elements" life was before long formed. Similar to this is the theory of Empedocles and Anaximander who believed that life had its origin in the interaction of the four

"elements": fire, water, air and earth. Anaxagoras believed that all animals were generated out of three elements: water, fire and earth. Thales thought that the ocean was the parent of all things.

Other philosophers explained the origin of life in the presence on the earth of a duality of forces called "Yin-Yang." "Yin" gave life to females and "Yan" to males. In these females and males all living things have their origin.

As regards the cause of the origin of life, ancient Chinese thinkers have only ambiguous answers. Like modern evolutionists, Chuan-tze (born 330 B. C.) and Lao-tze formulated their theories which had nothing to do with God. Lieh-tze said, "Various forms of things are seen, yet how they could come is very hard to know, that we could not find the maker who shapes them." Chuan-tze, having a similar idea, expressed it by saying of a shadow, "A shadow says to itself: 'Am I present because of still some other thing?'."—and further, "Could a thing rise before another thing inasmuch as when a thing is already included in things it could not go before them?"—and further, "Ten thousand changes go on, and no one knows where they will end or when they have begun." Ordinarily we think in terms of cause and effect, and we try to trace the sequence of cause to the first cause. We may get still beyond this and ask what the cause of the first cause was. We think of one cause before another infinitely and beyond our reasoning. In fact, the question is this, "Is there a first cause?" and it remains unanswered. Chinese philosophers long ago pointed out the fact that we should not ask for the cause of the first cause because there could be no cause preceding the first cause; otherwise it would not have been called the first cause.

Origin of Forms of Life

How have the various forms of life come into existence? Two conflicting hypotheses have been presented: special creation and evolution. According to the first supposition, species were separately created and definitely fixed types of life, whereas by evolution we mean the continuous developing of things from the homogeneous to the heterogeneous, from the simple to the complex. Theories formulated by the ancient Chinese belong to the latter hypothesis.

Dating back as early as the sixth century B. C., Confucius in his "Yi-ching" tried to show that complexity was derived from a simple source. The "Yi-ching" also expresses the idea that things were originated from a single simple source through "gradual unfolding and branching." According to the ancients, the alpha of the universe is simplicity, which changes, evolutes and multiplies into this complex, compound, manifold world. The Taoist's *Tao* and Confucius's *Yi* are almost identical. The truth is that the world changes from the homogeneous to the heterogeneous; some call the process Tao, others call it Yi, while we call it evolution.

The process of evolution as conceived by the ancients is a continuous development. The following passage from the "Yi-ching" appendix illustrates this idea very well: "Following the existence of heaven and earth, there is the existence of all things, there is the distinction of sex. . . ." This is the principle of continuity. Man is an object of nature and product of evolution and, as well as ants and bees, is but a transitional state in the natural evolution from lower to higher types.

Here are more stimulating paragraphs from Chuan-tze and Lieh-tze (fourth century B. C.). Chuan-tze's theory is the theory of *self-transformation,* which probably meant a gradual process of

evolution. He said, "The life of all living things is like the running of a horse, changing and moving at every moment. What do living things do? And what do they not do? They will naturally transform themselves." He furthermore definitely said, "All living things are species developing to various forms through the process of variation." He meant that everything is derived from some source, and by gradual changes they have become things of unlike forms. The dissimilarity does not appear at once; this is the result of progression, of development through generations of time. Here he states clearly the idea of variation, wherein lies the idea of origin of species.

Chuan-tze also understood adaptations, although he did not point out clearly that adaptation was responsible for the transformation of life. Chuan-tze stated: "When a man sleeps in a damp and moist place he will get sick and may die, but does this affect a fish? When a man dwells on a tree, he fears falling, but is it so with a monkey? Which of these is the right situation? Man eats vegetables; a deer eats grass, and a crow feeds on dead rats. Which of these is the right food?"

In another place he continued: "A horse can run a thousand *li* in one day, yet it can not catch one mouse like a cat, because they are different in traits. An owl can see an insect or the small tip of a twig at night, but can not see a mountain in the daytime, because it is different in structure from other animals." Here, then, is another important theory stating that with the structure goes the function.

Hui-nan-tze said: "Duckweed lays its roots in water, but the woody plant lays its roots in soil. Birds move in the air and animals move on solid things." Here are further expositions of the idea of adaptation.

How the changes take place, however, was not explained by these philosophers. Chuan-tze, Lieh-tze and Confucius had the conception of *Tao*. By *Tao*, Confucius meant change. The following quotation from Confucius will make this clear. "The heaven says nothing, but the four seasons run their course and all things are produced." To Lao-tze, *Tao* likewise meant "spontaneous life in the universe."

This is but a brief account of the ideas of evolution appearing among the speculations of ancient Chinese thinkers. While the Chinese anticipated many theories, collected a great variety of facts, invented some valuable propositions and brought a few to a high degree of philosophic significance, yet they have never pursued a single subject in a way calculated to lead them to final success. The variation, the adaptation and the structure-function theory—all were hinted at, but there were no results until centuries later when our western science stepped in and secured the prize.

SOME UNIVERSAL PRINCIPLES OF COMMUNICATION

By JOHN MILLS
BELL TELEPHONE LABORATORIES

All communication involves conventions and understandings as to the meanings of symbols, and it is usually through making symbols audible or visual that intelligence is transferred. When the distance is too great for unaided ear or eye, electrical systems apply. All those in use to-day derive fundamentally from the telegraphy of Morse and the telephony of Bell. Telegraphy and telephony, by open-wire lines, by cable, submarine and aerial, or by radio, however unrelated in origin, early development and commercial exploitation, are now more than sister arts—physically they constitute a unitary system based on common principles.

For Morse and Bell, working in the early days of modern science, batteries were the convenient sources of electrical currents although electromagnetic induction as discovered by Faraday was being applied to the development of generators. The motor action of a current was also known and was being rapidly applied. A simple motor action of which both inventors made effective use was the attraction by a current-carrying coil for an iron armature.

There were thus at their hands, although in rudimentary form, some of the essential elements of a communication system. It remained for the inventors to develop the still more essential concept of such a system and to supply the remaining elements. Time has refined their elements, conceived more basically, developed or adapted new principles and mechanisms; but, broadly speaking, their elements are typically those necessary to any system of communication. First, there must be a source of energy which can give rise to an electrical current; second, a mechanism for varying this current in conformity with the speech or signal which is to be transmitted; third, a medium for this transmission, and last, a mechanism which will translate the current variation into speech or signal. For Bell the second element was the telephone transmitter; for Morse, the telegraph key. For both the fourth element was an electromagnetic motor, in one case the lever which clacks in a telegraph sounder and in the other the diaphragm which vibrates like a drum head.

In the telegraph system the lever of the sounder reproduced the up-and-down movements imposed by an operator upon the lever of the key at the sending end of the line. The time between up-and-down movements was the basis of the code of signals. Relatively long intervals represented dashes, and shorter ones, dots. The receiving operator was enabled to perceive the interval aurally because the lever made characteristically different sounds when it struck against the upper and the lower stops. Visually sometimes the series of dots and dashes was recorded by arranging the down movement to bring a pen against a moving strip of paper.

In the telephone system, back-and-forth movements of a diaphragm, as occasioned by the sound-waves in the surrounding air, were reproduced in movements of the diaphragm of the receiver, and these established sound-waves intelligibly similar to the original. The code for the interpretation of these sounds was already adopted in the language conventions of the speaker.

By word or sign, therefore, but fundamentally by movement, is electrical com-

munication accomplished. The signs may lead, and soon did, to complete words, recognizable by the conventions for printed letters. By proper arrangements of the motions at the receiving station letters are printed on a moving strip of paper by an electrically operated typewriter. For this purpose the telegraph key at the sending station is replaced by equipment which includes a typewriter keyboard. The entire assemblage, then, becomes the so-called "printing telegraph." By other arrangements for the reproduction of movements, as in the telautograph, handwriting has been transmitted. And finally, by more elaborate and refined sequences of movements, images may be transmitted: picture transmission is a commercially available service, and television pauses at the threshold, a practical accomplishment of undetermined economic possibility.

These later systems involve the conscious and deliberate control of electrons. Such conscious control of electrons in communication systems dates from the development of the three-electrode high-vacuum thermionic tube. The tube was applied to long-distance telephony in the 1914 opening of Bell System service between New York and San Francisco and in the 1915 experimental transmission from Washington to Paris—the beginning of a development which has already linked to the American telephone system those of most of Europe.

In wire transmission the vacuum-tube became a circuit element; along the transcontinental line, for example, it was interposed at Pittsburgh, Chicago, Omaha, and so on, to amplify successively, as they became too much attenuated, the complex but feeble currents of telephony.

In radio transmission the tube was utilized in the terminal equipment. At the sending station it gave rise as a generator to the high-frequency radio current, varied and modulated this in conformity with the current from a telephone line or transmitter and then amplified the resultant current, with its hidden speech significance, millions of times to impress it upon the transmitting antenna. At the receiving station other vacuum-tubes reversed the process of modulation, that is, detected in the antenna current the modulating cause and obtained a current similar to that in the original transmitter which they then amplified and sent on its way to the distant telephone receiver.

Long before commercial radio-telephone service with the European continent was initiated—since its development, requiring among other things studies of an unmapped transmission medium, was interrupted by the war—the principles of operation just described had been applied in so-called carrier systems of telephony and telegraphy to the more efficient use of the long-distance open-wire network of the Bell System in the United States. Where a single pair of copper wires had previously transmitted at any instant only a single conversation, properly designed terminal equipment, employing vacuum-tubes, permitted as many as four simultaneous conversations. Each conversation had its speech significance carried by a distinctive current—a current of frequency different from those assigned to the other conversations. Multiplex telegraphy followed the same principle, using distinctive currents for each telegraphic channel.

The vacuum-tube also has its part in the system for the transmission of photographs, which was well established on the telephone lines of this country by 1925, and has a part in the recently demonstrated systems for television. In both these more recent developments, however, another electronic element—the photoelectric cell or electrical eye—

plays the leading rôle in the terminal apparatus. This cell is a light-sensitive device which gives rise to an electric current always accurately proportional to the amount of light which falls upon it. In television, still another device, utilizing known actions of electrons, plays the counterpart to the photoelectric cell. This is the neon tube, an electric lamp keenly sensitive to variations in its electrical supply.

All these systems of communication, wire and radio, whether for telegraphic signals or spoken word, or for a scene—all these systems operate on certain common physical principles. With them there might be included the systems for sound pictures, of which two developed in Bell Telephone Laboratories are in wide use to-day. These, also, are telephonic systems, but in them transmission is divided into two steps by an intervening act of recording. In one system the record is cut by an electromagnetic graver on a wax disc; in the other it is photographically recorded on a strip of film as a series of striations of varying photographic density. In the disc system reproduction comes through a special form of telephone transmitter actuated by a needle which follows the groove in the phonograph disc. In the case of the film an electrical eye observes from instant to instant the varying photographic density of the sound record and gives rise to a corresponding current.

Any communication system to-day involves apparatus for two distinct purposes: the first is the production of a channel for communication with its related terminal equipment; the second is the control, switching and supervision of the channel.

In complexity and first cost the apparatus required for the second purpose may exceed that for communication proper. This is particularly true in the short-distance communications of large metropolitan areas where improvements in reliability, speed and facility of service are obtained by bewildering assemblies of apparatus in the huge central officers. In the panel-type dial system, for example, there are complicated assemblies of small electromagnetic devices, intricately interconnected, each of which serves in lieu of an operator and constitutes an electrical brain of the system. Each assembly receives from a subscriber's dialing operations the same statement of desired numbers as would an operator, storing the information within itself. It then proceeds as would the operator, consulting a routing guide, to handle the call until the distant party answers or until it reports back that he fails to do so.

Within these decoder senders, as they are called, hundreds of operations are performed successively for every call of a subscriber to which they attend. They must do their appointed tasks accurately; and, because they are complicated and expensive, should they fail they must be promptly inspected and readjusted. In their more recently designed forms, therefore, new cerebral functions are being provided. Should one of these senders in its sequence of operations fail at any point it will, of its own action, disconnect itself from the line of the subscriber whom it is answering and report to a maintenance man. Even more, for his information it will print on an electric typewriter the number of the operation at which it failed. Could more human intelligence and efficiency be demanded of any organism than that it should quit work when diminished powers endanger its further acts, call for help and accurately diagnose its own complaint?

Of the apparatus in a communication system concerned primarily with transmission there are to be distinguished three groups: namely, transmitter, medium or channel for transmission and

receiver. The terminal equipment is fundamentally apparatus for energy conversion, and receiver and transmitter usually perform complementary operations. In telephony the transmitter is a sound-sensitive device actuated by the mechanical energy of sound-waves and giving forth electrical energy. The receiver is a sound-active device, converting electrical energy into mechanical energy. In ordinary telegraphy the transmitter involves a key whose up-and-down motions at the hand of the operator are reproduced by the bar of the telegraph sounder at the receiving station. In picture transmission a light-sensitive cell receives varying illumination depending upon the photographic density of the negative which it is scanning; and at the receiving station a source of light and an electromagnetically controlled shutter serves as a complementary light-active device. In television a tube of neon gas, which responds to the current impulses from the light-sensitive cell of the distant transmitting apparatus, is the complementary light-active device.

In principle it makes no essential difference whether the transmitter acts to convert mechanical into electrical energy or acts to control a source of electrical energy. Of the first type was the original telephone transmitter of Bell, which converted the vocal energy of the speaker. Incidentally the same device also functioned as a receiver performing the complementary conversion. The transmitter, however, with which Bell sent the first complete sentence, like most of those employed to-day, was a device for controlling the current from a battery. Its energy output depended then not upon the vocal power of the speaker alone but primarily upon its efficiency as a controlling mechanism. In telegraphy, in the same way, the energy output of the sending key does not depend upon the operator but upon the battery which the key controls; and at a receiving station the energy of the received current is not directly converted into sound but serves to control another battery which supplies energy to the sounder.

In general words, therefore, a transmitter operates to control, that is to modulate, the current from an energy source in conformity with the signal to be transmitted. It makes no difference whether the current which is modulated is otherwise unvarying or not. An alternating current would serve provided that it did not have a periodicity, that is a frequency, which would be confused with that of the signal itself. Both Morse and Bell, working in the early days of the electrical arts, employed batteries, which were the energy sources then available, and so used unvarying currents, that is currents of "zero frequency," as we would say to-day to preserve the generality.

Those who followed Hertz into radio used the highly damped and alternating discharges of condensers through inductive circuits and thus employed groups of high-frequency waves. For telegraphic purposes these proved entirely practical since the high frequency was efficiently transmitted from their antennas, and the group frequency, being greater than the frequencies involved in the dot and dash signals of their code, gave rise to no confusion. When, however, they came to attempt radiotelephony, among their many difficulties was the fact that their currents involved frequencies which confused the listener, being in the frequency range that should have belonged solely to the voice-modulated currents.

The difficulty was to be overcome by the adoption of a generator of so-called continuous waves. In the 1915 transatlantic experiments, a vacuum-tube acted to convert energy from direct-current sources into a high-frequency. The current had a definite and single

frequency determined by the capacity and inductance which were associated with the tube. This current was then modulated by the speech current from a transmitter, amplified and impressed upon the antenna. The modulated current was highly complex, including as components the carrier current itself and the products of modulation; but the important thing about it was that its component of carrier current was of a single frequency. The carrier currents which had been utilized in the early attempts at radio-telephony had not been of single frequency but complex currents involving components of a wide range of frequency; and corresponding to each of these components there had been products of modulation, giving rise to confusion much confounded.

The nature of the confusion appears from a consideration of the act of modulation of a single-frequency current by a transmitter current itself involving only a single frequency. A tuning-fork produces essentially a single-frequency note. Imagine its sound to actuate a transmitter and the resulting current to modulate a carrier current. For convenience of arithmetic assume the carrier frequency to be 100,000 cycles per second and the fork frequency 1,000. The current from the modulating device, which is again the versatile vacuum-tube, will have three high-frequency components, one of the frequency of the carrier and the others so-called sidebands. These are respectively above and below the carrier frequency by the amount of the modulating frequency, and so are 100,000 + 1,000 or 101,000, and 100,000 – 1,000 or 99,000.

If, however, a complex sound, involving notes of several different frequencies, actuates the transmitter each note will produce its sidebands. The intensities of the currents in each pair of sidebands will depend upon, and be directly proportional to, the intensity of the component note which produces them. Music or speech may thus be hidden in sidebands of modulated current and transmitted as high-frequency currents.

At the receiving station another vacuum-tube acts to produce currents whose frequencies are sums and differences of those impressed upon it. If the currents of the previous arithmetical example are received the difference terms will be currents of frequency 1,000, that is, of the original modulating frequency. These are easily distinguished from the high-frequency currents, and when passed to a telephone receiver they produce the same sound as if they had been directly transmitted to it and none of the intervening operations had been performed.

The modulated currents and their accompanying carrier current form a group relatively easily separated from any other similar group if the frequency bands of the group do not overlap and are not too closely adjacent. The allowable closeness depends upon the sharpness of discrimination of the selective circuits which are used for that purpose; and that again depends to some extent not only upon the engineering skill of their designers but also upon the economically allowable complexity and cost of the circuits. In present-day radio broadcasting the carrier currents which are utilized by the stations in any particular area are legally separated by 10,000 cycles. The allowable separation of carriers, however, in order that one radio station's output shall not interfere with that of another through being simultaneously received and at too nearly the same loudness, depends upon the range of frequencies which the sidebands must involve in order that they shall contain the essential notes in the speech or music of the program.

What range of notes is essential for reproduced speech depends upon the occasion. For intelligibility a compara-

tively small range is required; naturalness demands more; and for essentially complete illusion, such as sound pictures require, still wider range is needed. For a telephone conversation, where a voice is to be recognized and its nuances of inflection appreciated, the range from 100 to 3,000 cycles will serve; but the range from 60 to 7,000 is none too large for an esthetic illusion from a "talkie." Music, particularly of stringed instruments, requires a wider range than speech, but very good effects can be obtained with only a slightly larger range when it is unaccompanied by pictures.

For signals other than those of music and speech, the necessary range of frequencies which must be allowed to the sidebands depends upon the character of the signal and the speed of signaling. In telegraphy, for example, if a dot occupies half a second and is separated from the succeeding signal by an equal interval of time, obviously a frequency of one cycle per second must be allowed. But this frequency is insufficient for good definition of the received signal because the abrupt change of current from zero to its full value and back to zero, as occasioned by the telegraph key, is not equivalent to an alternating current of a single frequency. Instead it is equivalent to a complex alternating current involving a whole series of frequencies, three, five, seven, and so on, times the frequency which at first glance one would assign to the dot. Essentially complete simulation is obtained if frequencies as high as eleven times are transmitted and received.

Whatever the maximum number of dot signals which the telegrapher wishes to be able to transmit per second, allowance must be made, therefore, for a sideband with a frequency range eleven or so times as large. As a rule, a band of one hundred cycles does very well for the ordinary speed of telegraph signals. Speech and music, as earlier figures showed, require more, but television imposes the most severe requirement.

In any television system which can be imagined, some mechanism must send electrically information about the relative light and shade of successive elementary areas in the scene which is to be "televised," as the newspapers would say. This information must be applied at the receiving station to the reconstruction of similarly arranged elementary areas of light, differing in intensity according to the information transmitted. Furthermore, the complete scene must be reconstructed in a time within the limit of the persistence of vision of the human eye, that is, under one sixteenth, perhaps only one twentieth, of a second.

Imagine, as may well occur, that one elementary area of the scene is bright (when current must flow) and the next adjacent practically dark (when there would be no current to be transmitted). The condition corresponds exactly with the sending of a dot in telegraphy. If the scene is analyzed into 10,000 elementary areas—and this would correspond to the detail in one square inch of 100-mesh halftone—there would need to be the possibility of transmission of 5,000 dots for each time the scene is reproduced, or approximately twenty times as many dots per second. That means a width requirement for the sideband of 20 times 5,000, or 100,000 cycles per second. Such a requirement is equivalent to that of approximately one thousand telegraph channels or thirty (commercial) telephone channels or ten adjacent channels for radio broadcasting. Therein lies a specific economic limitation for the future of television.

In fact, there is a general limitation for all forms of communication. Given a communication channel effective for transmitting a definite range of frequencies and given a type of signal to

be transmitted, simple arithmetic permits a determination of the speed at which the signal can be transmitted; or, what amounts to the same thing, if the frequency requirement of the signal is less than that which the channel will permit, then the number of signals which can be simultaneously transmitted may be determined. An interesting illustration of this principle was given by R. V. L. Hartley, who first stated it.

In substance he said, let us imagine a line capable of transmitting all frequencies from zero to 3,000 cycles. This would be sufficient for a good telephone conversation. We now imagine the current from the speaker's transmitter to be recorded, as on a phonograph record. We then turn this record for reproduction at twice its recording speed, reproducing from it electromagnetically and transmitting over the line to the distant station. For the transmission of the speech we use the line but half the normal time. At the other end we again record it but now at double the normal speed of the turntable. We then reproduce for the listener at half that speed, that is, at just the speed of the original record of the distant speaker. At first thought it would appear that we could do the same for another pair of speaker and listener and utilize the remaining free time of the line for that speech and thus obtain a double efficiency for our line.

The fallacy resides in the fact that neither speech would be adequately transmitted. Reproducing with the turntable run at twice normal speed would mean that any frequency originally recorded would be doubled; a sound of 1,500 cycles would become one of 3,000. Since the line, by assumption, will transmit no frequencies above 3,000 no sounds with original frequencies above 1,500 cycles will be transmitted. In effect, therefore, half the frequency range of the message would fail to get through, due to our hurry. Similarly, of the other message what might be called a half would get through; and we would obtain halves of two different messages instead of both halves of one. There would be no gain, and in fact a loss since neither message would have its desired intelligibility.

Halving the time utilized in transmission always requires doubling the range of frequencies which the channel must transmit. We can't gain by beating the devil around the stump, and in practice the communication engineer doesn't try. In practice it works out that the effort is confined to using to its fullest the transmission range of each medium, to placing the sidebands of various signals as close together as possible and to avoiding the transmission of any unnecessary bands of frequency.

Two illustrations show the practice. Wire lines in the Bell System are multiplexed for transmission between stations over distances long enough so that savings due to more efficient use of channel are greater than expenses due to added terminal apparatus and operation. Telegraph messages, for example, because they require a frequency range from zero to about 100 cycles per second, are sent over the same pair of wires as telephone messages which require from about 100 to about 3,000 cycles. In other cases some ten telegraph messages, with their bands adequately separated, are sent over the normal pair of telephone conductors. Sometimes by suitable terminal equipment there are transmitted over the same pair of wires not only the telegraph message and normal telephone message which together occupy about 3,000 cycles but also a second telephone message, occupying a similar range but carried by a high-frequency current and utilizing the transmission capacity of the line for frequencies as high as 10,000 cycles. In still another instance the lines are specially condi-

tioned, and a frequency range is made available from zero to about 28,000 cycles. Over such lines, by suitable terminal equipment, there may be sent in addition to the ordinary telegraph message and telephone message a total of three more telephone messages. In such cases, however, each of these additional messages is divided into outgoing and incoming portions and a frequency range of 3,000 or so cycles assigned to each portion. The various messages, therefore, use about twenty-one of the available twenty-eight thousand cycle range, the remainder being lost in providing adequate separation between the bands of the various messages.

The other illustration is found in the long-wave transmission system which provides radio-telephony with Europe. There new methods have resulted not only in increased efficiency in use of the available frequency range but at the same time in economies of operating power. Instead of transmitting the carrier frequency and both sidebands which result from its modulation by speech currents, only one sideband is transmitted. For purposes of reception a current of the carrier frequency is locally introduced at each receiving station and hence demodulation proceeds practically in the normal manner. In addition, by properly disposing the transmitting and receiving antennas in America and in Great Britain and by special equipment it is possible to use the same frequency of carrier for both outgoing and incoming parts of the telephone conversation. There is thus withdrawn for transatlantic telephony from the general ether channel the narrowest band possible for telephony, namely, that corresponding to the frequencies essential to the intelligible and natural reproduction of the human voice.

SYNTHETIC SEAS

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Suppose that all the water in the world were to be destroyed. Do you think we have enough scientific knowledge and practical ability to make a substitute for it?

If we can make any liquid at all, we ought to be able to produce one to replace as simple a compound as water. And, because the loss of water would be a great blow to everybody, we could get all the world to concentrate on replacing it. With this initial confidence, let us see what are some of the conditions that would have to be complied with.

Right within our own bodies and within the bodies of other living creatures our new liquid would have to perform many functions. Water is far more vital to us than food. People can live a long time without food, but it is an exceptional person who could exist more than three days without water. About 75 per cent. of our bodies is water, and if a person were to lose 20 per cent. of the water content of his body he would die. The blood, which itself is mostly water, distributes food to the cells as well as oxygen to burn the food. It returns bearing the ashes of the body fires. And, strange to say, one of those ashes even is water, because the hydrogen in the food burns to water. Thus water is actually manufactured in the body—about a pint of it every day. The liquid we are going to make will have to perform every one of these necessary functions, and the process by which it is manufactured must be one that can be carried on right within the body itself.

Because people must be able to drink our substitute for water, it must have no taste, and no odor. It must also be able to purify itself from harmful bacteria simply by flowing in air and sunshine. Otherwise it would soon become unfit for drinking.

Our liquid must be suitable for performing another remarkable function in the system, which water does in an ideal way. It must regulate the body temperature. Whenever the body gets too warm, water is forced out through the pores of the skin, and evaporating there carries heat away from the body. Dr. Slosson has said that water is twice blessed. It bestows a blessing as it comes and as it goes—especially as it goes. We appreciate the coolness of a cold glass of water, but it is many times as cooling later on as it issues and evaporates from a million pores. Even a cup of hot tea cools one off, because as it vaporizes from the skin it carries away with it fifty times as much heat as was taken into the body with the hot tea.

Our substitute for water will have to be able to play an important rôle in the lives of plants, too. It will first have to keep the ground soft enough for tiny roots and sprouts of plants to penetrate. It must be capable of being absorbed out of the soil by the plant roots, and of coursing up through the plant, bearing along with it a load of mineral matter dissolved out of the soil. Then, under the influence of sunlight and the green coloring matter of the leaves, some of our substitute for water must unite with carbon dioxide to build up the tissues of the plant, and the remainder of it must pass out through the pores of the leaves and evaporate off into the surrounding air. Later on, it will have to fall again as rain and cleanse the plant from accumulated dust, and then sink into the

soil, only to pass up through the plant again, and so on and on in an infinite cycle.

Our new liquid will have to fill the needs of the kitchen, also. There it must be used for washing things: food, dishes, tables, floors, windows, everything. But its most important use will be to cook with. And, if our liquid is to be used for cooking, it will have to boil at a temperature that is suitable for cooking. Thus, it would be a big nuisance to the cook if our substitute for water were to boil at too low a temperature, for then no cooking could be done except in pressure vessels. The same liquid that is used in the kitchen for washing and for cooking must also be used as one of the principal ingredients of many of the foods prepared there. In fact, we eat no food that does not have water either added to it or already present in it. There is water in soups, in vegetables, in meats, in salads and even in bread and in cakes.

Another fortunate characteristic of water that our liquid will have to have is that it does not boil away very fast. A kettle of water over a hot fire boils and boils and boils for an hour or more, and still there is plenty of it left. Even after a vessel of water has been heated up to the boiling point, it takes seven times as much heat to convert it from a liquid to a vapor as it did to warm it from 70 degrees up to its boiling temperature. The heat required to boil off a gallon of water is nearly ten times as great as for some other liquids. It is this fortunately high latent heat of water that keeps it from boiling away so fast, and that makes it evaporate out of rivers and seas so slowly.

Ice or frozen water is used in the kitchen also for cooling. It cools the refrigerator, and it chills drinks and salads. Melting ice, with its high heat of fusion, makes a little section of the Arctic Circle pass right through the kitchen. And besides, it is water in the steam radiator that heats the kitchen in winter. So, if our liquid is to replace water in the kitchen, it must be suitable both for heating things and for cooling them.

Another important requirement that our new liquid will have to meet is that its vapor must be lighter than air, just as is the case with water. If water vapor were heavier than air, then there would be no clouds and no rain. When the vapor of water mixes with the air just above the surface of the earth it makes the lower layer of the atmosphere lighter than the drier air above. And so the heavier atmosphere above settles down toward the earth, and the lighter water-laden air rises into the higher atmosphere. It is cold up there, and the water vapor is condensed to visible droplets that we call clouds, from which the earth gets the rain that purifies and cools the air, cleanses vegetation and makes all life possible.

But suppose water vapor were heavier than air. Then there would probably never be any rain, because the heavy water-laden atmosphere would stay near the surface of the earth. Not only this, but we should often be living in a dense fog as bad as those in foggy London, which the Londoner sometimes compares to pea soup. So this matter of density of its vapor, also, must be taken into account when we make our liquid, for a chain is no stronger than its weakest link.

And here it should be said that there is a conflict between the essential qualities of lightness of vapor and correctness of boiling point. For a compound whose vapor is lighter than air, the boiling point of water is quite abnormal. If water as a liquid possessed the same physical constitution, or if it existed as a liquid in the same state of molecular aggregation as it does as a vapor, its boiling point would be around 212 de-

grees *below* zero, instead of 212 degrees *above* zero as it happens to be. So here we must make a compound whose vapor is lighter than air, but whose boiling point is more than 400 degrees higher than such a compound normally would have. In order to do this we will have to find a compound whose molecular weight decreases as it changes from the liquid to the vapor state.

And then, too, the vapor of water in the air has a tremendous influence upon climate. Water vapor in the atmosphere acts a little like a wool blanket wrapped around the world. It lets the bright heat rays from the sun filter in to warm the ground, but it stops the dark heat rays reflected back from the ground, and prevents them from radiating away and being lost. If it were not for water vapor in the air we should not have the pleasant climate that we have become accustomed to. Instead, the temperature would probably be much like that which prevailed here during the prehistoric ice age. The compound we are to make will have to be able to influence our climate just as water does, of course.

Another thing about water that we must not lose sight of is its usefulness as a means of transportation. Man has swum in it and navigated it by means of logs, canoes, boats and ships since the earliest times. And water is suited to that purpose in an admirable way. It is dense enough to buoy up heavy objects, and at the same time it is mobile enough to flow with great freedom. Suppose water were as light as gasoline. Then men or animals could not swim. Even wood would sink. Boats would not be so useful, because they could not carry such large loads. A wreck at sea would be a much more terrible thing than it is now, for everybody on board would sink like stones. To fall into the water would mean almost certain death. Even fish would need to be much lighter than they are.

Speaking of fish, if it were not for the fortunate fact that water dissolves air in considerable amounts there would be no fish as we know them, for even fish must have air. But, because water does dissolve life-sustaining air, the population of the waters of the world is much larger than that of the land. Life must be possible both on and within the liquid we are going to make.

There is also another unusual property that must be put into our substitute for water. When frozen into ice it must be lighter than when in the liquid form. If ice were heavier than water, it would sink to the bottom as fast as formed and settle there, a frozen mass. It would not melt in summer, either, because the water above the ice is such a poor conductor of heat that little of the warmth of summer would ever penetrate down to it in its protected bed at the bottom of river, lake or sea. With each succeeding winter our lakes, our rivers and even our seas themselves would gradually accumulate ice at their bottoms, until finally they would be just one solid mass of ice.

We will have to make some very special provisions to get incorporated into our new liquid this quality of being lighter after it is frozen than before, because that is not a usual property of matter at all. Nearly all liquids contract when they freeze, and so get heavier instead of lighter as they pass over from the liquid to the solid state. And even water contracts as it cools until it reaches a temperature just a little above freezing. But there it reverses its behavior completely and begins to *expand* as it is cooled still further. The effect is that after water has been frozen to ice it occupies a larger volume than the same weight of the liquid. The reason why ice floats on water is that water has a fortunate property that is not common to other things in nature.

Another valuable thing about frozen water that we will have to make sure to incorporate into our liquid is that it always forms very slowly, even on extremely cold nights. As water freezes, the process of freezing is greatly retarded by the heat given off during the freezing process. The amount of heat liberated during the freezing of water is so large that it actually takes four times as much cold to make a pound of ice out of a pint of water at its freezing point as it takes to cool the pint of water down from 70 degrees to its freezing point. This large heat-evolving property of water as it freezes has a tremendous influence in slowing up the formation of ice and in keeping bodies of water from freezing solid in winter. The heat given off by freezing water actually helps to moderate the temperature of cold nights, strange as that may seem.

Still another one of the essential uses of water that we will have to incorporate into our new liquid is as a medium for developing power. Water that has been drawn up into the clouds by the energy of sunshine and then poured down on the high-lands as rain is employed directly to turn the wheels of industry as it hurries back down to the sea. And then steam is made to do useful work for mankind. One quart of water makes 1,700 quarts of live steam. By means of the steam engine, this immense expansive force of water has been made to change the whole economic system of the world, greatly enlarging the scope of people's activities.

Coal is ordinarily thought of as being the most essential thing around a steam power plant. But that is not true, at least with respect to the amount of it that is used. For each ton of coal fired in an up-to-date power plant, from 500 to 1,000 tons of water are required. The reason for using more water than coal in the steam power plant is that water is employed there both for generating pressure and for reducing pressure, paradox though that may seem. The effective push given to the pistons of the steam engine depends upon the difference between the pressures at the inlets to and at the outlets from the steam cylinders. This differential is made as large as possible by introducing water to the cylinders in the form of live steam under high pressure, and then condensing the steam back to liquid water as it leaves the exhaust. The result is that on the exhaust side the pressure is actually reduced to a minus value, or to a vacuum, thereby making the greatest possible differential between the port where the high-pressure steam rushes into the engine and the point where it later leaves the system as liquid water at almost no pressure at all. It is water, of course, that is used for reducing pressure by cooling and condensing the exhaust steam.

Our substitute for water must be good for putting out fires, and for cooling the fever of the sick. It must not be too light, nor yet must it be so heavy as to float away the stones and the soil like pieces of wood. In winter it must not rush out of the sky in large nuggets like hail, but it must come down in gentle flakes and spread a warm blanket over the freezing world. It must not be capable of being burnt up or destroyed in some unsuspected way. It must be able to go through many changes and many conditions, and still retain its original composition and characteristics. The supply of it must not diminish with time. All these essential properties water has. Every hydrogen-containing compound that burns raises the water supply of the world. Every automobile engine manufactures water. Water vapor pours from the smoke stack of every power house and from the chimney of every home. The American automobile alone increases the amount of water in the world by 250 million barrels a

year—as much as is used by a city of 300,000 people. As the world's supply of combustibles is going down, its reserve of water, that life-giving and most useful liquid which we will have to replace in some way, is going up.

In spite of all its perfectly amazing qualities, water, as we have known it so intimately and so long, is composed of just two common gases—hydrogen and oxygen. If 1,244 volumes of hydrogen gas are mixed with 622 volumes of oxygen gas, if the little individual particles are caused to combine and then if the vessel is cooled off afterwards, there is obtained one volume of liquid water. To squeeze those 1,866 volumes of the mixed gases down to the one volume that the desired product occupies would take a pressure of 25,000 pounds on each square inch of surface. To hold together just one pint of water, the equivalent of over a million pounds pressure has to be supplied.

But, of course, we can not hold our new compound together with a push from the outside. We will have to utilize a pull from the inside to tie the components together, as is the case with water, and it will have to be a very strong pull too. This means that in selecting the components of our new liquid we are limited to those that have a natural affinity for each other.

And, another thing, where in the world will we get enough basic material to make our new supply of liquid out of? Can we find large enough amounts of a pair of gases similar to hydrogen and oxygen that may serve the purpose? One of the easiest ways to get the answer to this question of source, perhaps, is to find out how much hydrogen and oxygen had to combine forces to make the world's present supply of water. By far the most plentiful gas that is known now is air. A measure of the amount of air there is may be had from the fact that the shell of air around the earth weighs enough to press down on each square inch of surface exposed at sea level with a force of about fifteen pounds.

But, if all the hydrogen and oxygen that make up the water in the world were to be let loose above the earth, the pressure, instead of being fifteen pounds on each square inch, as at present, would be 400 times as great, or 6,000 pounds. Since air is the most plentiful gas we have now, it is quite evident that we can not find 400 times as much of any other gases, which is the huge amount that would be needed to produce a substitute for all the water in the world. Liquids, too, seem to be out of the question as sources of our substitute for water, because water itself is by far the most plentiful liquid in the world.

Do you think there is enough scientific knowledge and practical resourcefulness in the whole world to permit us to make a liquid that will incorporate at once all these necessary qualities that water has, and still that will not have a single undesirable quality to clash with other things in nature or to upset in the least her great and intricate cycle? To this question there seems to be but one logical answer: "No."

WEATHER HAZARDS IN AVIATION

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THERE are two principal sources of danger in civil aviation: first and most important up to the present time, those connected with the machine itself, *i.e.*, the plane or ship; and second, those arising from discontinuities in the medium —the air—in which plane and ship function, or what we call adverse weather conditions.

The second source will probably soon become the more important inasmuch as there is a betterment each year in the steadiness of performance of the machines. On the other hand, there is little prospect of control of the atmosphere, and all that can be done is to give warning of the likelihood of dangerous conditions. After that it becomes a matter of judgment on the part of the pilot as to what route, if any, will be attempted.

In various papers the writer has set forth at some length the need at airports of *up-to-the-minute airgraphics,* that is, continuous observing and recording of the physical processes involved in the condensation of water vapor in the free air, for it is our belief that a short and serviceable definition of weather is— change in state of water vapor. It is water, whether as cloud, invisible vapor, hail, sleet, glaze, snow or rain, driven by the air stream and responding to temperature discontinuities, which makes weather and does mischief. Even in the acquisition of a charge of electricity and the making of a disruptive discharge like lightning, it is the cloud droplet which is the villain in the play.

Cloud formations, therefore, must be studied *intensively* at all airports; not only must height, direction and velocity be given, but serious effort must be made to read in the cloud itself the story of the stratification of the vapor, the temperatures, the percentages of saturation, the densities per unit volume and the electrification of the cloud droplets. This might well be called vapor structure. An example is readily found in the cumulo-nimbus cloud, which is an upthrust of cloud-stuff into higher strata, indicating accumulation of electrical charges just as plainly as a salt dome indicates the proximity of oil in geological structure.

At present, condensed water vapor, or cloud, is the best agency by which the observer on the ground can tell what the air streams are doing at various levels. True, pilot balloons and sounding balloons are in use to detect air currents and thus far have been the main reliance of aerographers; but in addition to expense and uncertainty of data, pilot balloons give no temperature or vapor-content data, and sounding balloons give records that are not available until many hours or days have elapsed. It is necessary, therefore, to rely chiefly upon cloud measurements. Blue Hill Observatory, under the late Professor Lawrence Rotch, was the pioneer and for a long time the only institution in this country using sounding and pilot balloons, and it is fitting that a plea for the use of improved cloud-measuring apparatus should come from this observatory. When clouds are not present, artificial clouds must be formed by smoke trails from rockets and shell bursts.

The weather hazards then to be considered are thunderstorms and lightning, fog and ice formations and ***anakatabats,*** or up-and-down air rushes.

Lightning

Are aeroplanes and airships liable to be struck by lightning? The answer is, "Yes!" If it can be avoided, airmen should not fly close to cumulo-nimbus clouds, or attempt to pass between layers of dark clouds of the nimbo-stratus type. (The word nimbus is now considered by aerographers as an adjective rather than a noun and indicates any type of cloud from which rain is falling, so that, to be more accurate, we should say nimbus cloud sheets, whether cumulus, stratus, pallio or grandineus). Fortunately, the great majority of cloud types are harmless and apparently without noticeable electrical charge.

We do not know positively how a cumulo-nimbus cloud becomes electrified, the acquisition being both rapid and intense. We do know that friction of one solid with another will produce electrification, especially in cold, dry air. It is also known that friction of a jet of steam or even cold water against a metal surface produces electricity. Dust clouds in motion become strongly electrified, and we can by circulating air vigorously against frost crystals produce intense electrification; but there is still much to be learned regarding the mobility of ions in the free air, the way in which charges originate on these carriers and the way in which, once acquired, the charge increases.

Dr. G. C. Simpson, as early as 1909, showed that by breaking up water drops in an air current there is developed an electrical separation, the drops becoming positively charged, while the air is negative. On the theory advocated by Elster and Geitel, the prime cause of the development of a high charge is to be found in the collision of rain drops in an existing field. Whatever the nature of breaking the droplets may be, the presence of an ascending current of approximately ten meters per second seems to be essential in connection with the change in electrification of an ordinary cumulus cloud to a cumulo-nimbus. The droplets for the most part are positively charged. Simpson has given several diagrams illustrating the air currents moving in at the ground, then rising until the base of the cloud is reached and penetrating with a filter effect. In the cloud the smaller drops are prevented from falling. There is separation of cloud particles and water, and there results an accumulation of positive electricity in that part where heavy rain, positively charged, begins to fall. The cloud remains negative. Simpson holds that flashes start from one portion of the cloud and are branched upward toward the negative charge in the main cloud, or downward toward the ground. He bases this on photographic evidence, but the conclusions are not beyond criticism. The accumulated positive charge in the region of separation is dissipated constantly by lightning, the cloud remaining negatively charged. On the other hand, Wilson is of opinion that the raindrops are negatively charged and the smaller particles positively charged, the clouds being thus of positive polarity.

It is evident that authorities are not agreed and that there has been more speculation than experimental determination of potential values in close proximity to the cloud base.

It may be mentioned, however, that during thunder-storms and in less degree during snow-storms, the potential gradient at a height of 500 meters often exceeds 10,000 volts per meter. It is evident, then, that a plane under a charged cloud is in a strong electrical field and by its very presence tends to break down the dielectric; and when a discharge does occur, the plane may be part of the path. Judging from what happens to kite wires, we think it quite likely that guy wires and metal parts of

small cross section will be fused under such conditions. Some rough calculations of the energy and voltage in the case of kite wire struck by lightning give 6.48×10^6 kilovolt amperes, approximately 7.5 kilowatt hours. The values will vary, however, depending upon the time factor. Thus if the time be extremely short, as it generally is, the voltage runs up to 13,000,000 instead of the 1,400,000, and the energy 25×10^6 KVA.

There are several instances of planes struck by lightning, with fracture of struts, fused wires and shattered ailerons, but thus far without loss of life. Whether such planes experienced intense flashes, or side-flashes of moderate intensity, must remain an open question. There are all degrees of lightning, from feeble to intense, from the tremendous rush of energy known as an impulsive rush discharge to the meandering horizontal flashes with many small ramifications.

Those of us who have studied the effects of lightning are almost inclined to believe that lightning is a law unto itself. Its vagaries are so numerous that the usual laws of current flow are not applicable. In some cases, a definition of lightning as an *electrical explosion* best describes the phenomenon, while at other times the current (or probably an induced surge) will travel long distances and be measurable. Additional knowledge is being gained daily by the experiments conducted by both the General Electric Company at Pittsfield, Massachusetts, and the Westinghouse Company of Pittsburgh, Pennsylvania. Discharges of 5,000,000 volts are available for experimental purposes. New timing devices, such as the cathode ray oscillograph (a beam of cathode rays deflected in a strong electrostatic field, the particles being electrons and practically without mass), enable the experimenters to record in microseconds, *i.e.*, millionths of a second. Peek's experimental work with near lightning is a far call from Franklin's "fire of electricity" described in one of his letters (July 29, 1750) antedating the kite letter two years. As previously stated, the time factor is all important in determining the character of a lightning flash. If some one will discover a means of damping or slowing down the rush of the negative electrons, the problem of harnessing lightning will be solved, for the energy involved is not greater than can be controlled. Also if means can ever be devised to interfere with the process of accumulation of charge on a cloud surface, we shall then be able to rob the thunder-cloud of its present potential danger.

There are some interesting changes in the electrical potential of the air just in advance of a cumulo-nimbus cloud, and in fact it is possible to measure the strength of the field and by watching the increasing voltage forecast as much as thirty seconds in advance the discharges. With each lightning flash the electrical tension is ended, but only for the moment, as it begins to rise again slowly if the cloud is some distance away and almost instantaneously when the cloud is overhead. There is, however, as yet no way of telling from what part of the cloud the flash will start.

Fog and Ice Storms

Fog has been considered up to the present time the cause of more mishaps than any other atmospheric condition. This menace is being steadily minimized by the introduction of ray-beacon flying and the use of new devices for determining accurately distance above ground. It is also possible to dissipate fog; and although experiments in this direction in the open have not as yet given satisfactory results, the expenditure of energy

being out of proportion to the results achieved, there is no doubt in the writer's mind that here, as with the lightning, it is only a matter of time and further experimentation before we shall have devices for this purpose operating in commercial aviation.

There are many kinds of fog, all formed by cooling of the water vapor, however the cooling may be brought about. It is important to know the number and activation of the hygroscopic nuclei, also the larger ions and dust particles. Here is a fine field for investigation, in the relation of the size of the fog droplet, the radius of curvature and consequently surface tension, to the electrical charge together with the chemical properties of the nuclei.

We are not certain whether ordinary dust particles suspended in the air are efficient condensation nuclei. It is not definitely known whether activation is a function of size or of chemical property and origin. We do know that smoke and the gaseous products of combustion make efficient kerns or centers, that is, good condensation nuclei. Possibly this is due to traces of chlorine, for the hygroscopic feature of sea-fog droplets is undoubtedly due to the presence of salt. Experiments made by the writer with electrified and non-electrified smoke indicate that the latter greatly accelerates fog building. As is well known, rapid expansion and consequent quick cooling of an air-vapor mixture cause temporary cloud or fog. The introduction of smoke and small hygroscopic kerns makes the fog denser and more persistent. On the other hand, the problem of fog dissipation finds a solution by rapid compression, dynamic heating and clarification due to electrifying. It also seems to be established that the passage of a plane through a cloud under certain conditions will result in the formation of a clear channel, due mainly to mechanical fractionation of the cloud-stuff. The nuclei with their vapor spheres and probably the intervening air cushions are both broken and scattered.

There are, of course, many types of fog formation. Those which directly affect airmen are ground radiation fogs and sea fogs. The former are dangerous in the matter of landing, but to a large extent this hazard is being reduced by the use of locating devices both on the field and on the plane. Radiation fogs are seldom very deep, and having sharply defined limits are easily surmounted. Sea fogs are chiefly due to a warm air-vapor mixture brought down to or over a cold water surface. In coastal flying or on transoceanic flights, it is only necessary to rise a few hundred meters to be above the fog. Both types are found when anticyclonic pressure prevails, or when lows are moribund, the radiation fogs generally without wind, the sea fogs sometimes with steady north or northeast winds.

Ice Storms

A plane may acquire in a brief time a load of ice which not only interferes with the instruments but also increases the parasitic resistance and deforms the aerodynamic lines of least resistance. This happens when a plane passes through a mass of subcooled vapor, whether visible as cloud or invisible. The rush of the plane probably destroys the droplet structure, and the vapor tension (which is considerable in the case of extremely small drops) is released, and a change of physical state results. Hence any surface in close proximity becomes coated with ice. This may form even on the hub of the propeller.

Several methods for ridding or preventing the formation have been tried, particularly coating with vaseline or oil, but without evident success. One must

watch thermometers carefully and particularly the wet bulb when flying through clouds in which the temperature is slightly above the ice point.

Ice Storms Proper

Somewhat different from the subcooling ice load described above is the load of ice which is acquired when flying through an ice-storm. We now deal with water that has not been long in the liquid stage, forming and falling at first as rain but passing through cold air strata and also coming to rest on a cold surface. This is glaze—or what was formerly called sleet. A coating of ice of this kind may soon become quite thick as the coating continues to grow, and by its mere weight it can force down the plane. Heating may be resorted to in the case of all-metal planes, and the ice melted, but the easier and more practical course is to rise to an upper, warmer stratum. Conditions favorable for ice-storms can be forecast with a high percentage verification, as they are zones of marked instability accompanying energetic cyclones in which temperature fronts are sharply defined and the progressive movement of the discontinuities can be anticipated. The aviator must be on the watch for warm, moist, southerly winds with underrunning cold, dry, northwest winds.

Anakatabats

This word from the Greek for up-and-down marches best describes the violent up-rushes and counter down-rushes of the air occurring when excessive temperature discontinuities exist, as in the case of thunder-storms, line squalls and all tornadic formations. The instability is such that with the slightest horizontal movement a torque is developed with rotary motion that may have a horizontal axis instead of the more common vertical. These major turbulences *are quite frequent on summer afternoons in slow-moving or stagnant low pressure areas.* They are essentially local in character, being different in this respect from the line squalls to be discussed later. Any marked convergence of horizontal air streams is quite likely to develop a strong up-rush, which in turn must increase the downward rush of air in the rear of the convergence.

Experienced pilots have stated that they have dropped as much as 700 meters in a minute or so when caught in one of these anakatabats following a thunder-storm. The wreck of the *Shenandoah* can be traced to the anakatabats in the southwest quadrant of a low which passed eastward slowly on the morning of September 3, 1925. A streaky cloud appeared in the north, building up rapidly. Without much warning the ship began to rise. An effort was made to keep the ship down by increasing the engine speed and turning the nose of the ship down at an angle of 18°. The uplift was still sufficiently great to overcome the effort, and in fact increased. Nor did the valving of gas help. Then came a fall accelerated by the down-rush of air as well as by loss of buoyancy. Water ballast was dumped from the control car. Probably this was a mistake, for caught in another up-rush, the ship rose rapidly to nearly 1,900 meters, only to be struck by a descending current of such violence that it began to spin violently, around a vertical axis, in a counter-clockwise direction while falling. The rotational strains caused structural breakage, followed by collapse of the control car struts and consequent tearing away and ultimate crashing.

We can by electrical apparatus give warning in advance of conditions favoring the development of thunder-storms and these anakatabats. In addition the

rate of advance of a cold front can be rather accurately estimated.

Line Squalls

These are developed on a rather long wind shift line, and while associated with thunder-storms, are as a rule restricted to much lower levels and indicate rotary motion with a horizontal rather than vertical axis. Here again it is a question of temperature discontinuities as brought about by the conflict of air streams of different origin. The wind changes direction suddenly from south or southwest to northwest or north. In other words, the western limit of warm moist winds is suddenly swept aside by the eastern front of an on-coming high. Heavy rain with marked cooling accompanies the restoration of equilibrium. The whole mechanism is not quite as simple as here indicated, for the front edge of the surface cold air may be forced upward over a part of the retreating warm air. In other words, a tongue of cold air may penetrate the warm air mass at a height of 100 meters or more, running thus in advance of the main body of cold air which eventually displaces completely the warm air from the surface up. The cloud transformations are good exponents of the turbulence and give us some notion of the structure aloft which, however, can not be seen in its entirety from the ground.

IS EVOLUTION A CONTINUOUS OR DISCONTINUOUS PROCESS?

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THE various theories of "mutation" or "saltation" were offered at first largely as alternatives to the natural selection principle as conceived by Darwin. Whereas the latter made use chiefly of the ordinary quantitative differences shown by nearly every part of every plant and animal, the earlier views of the mutation school agreed in basing evolution upon a quite different and much less abundant type of variation. The mutations, to which they appealed, were discrete steps of quite appreciable magnitude, which, in some cases at least, might transmute the entire organism. Selection, so far as it was recognized at all, was supposed to act upon the finished products of the mutative process. According to De Vries, it was a matter of the survival or non-survival of *species* rather than individuals, though the species which he had in mind were commonly subdivisions of the groups so recognized by taxonomists.

In favor of such a view-point a great variety of arguments was offered. So far as these related to the supposed inadequacy of the natural selection hypothesis, they had, for the most part, been discussed by Darwin himself. Although now familiar to every student of the literature of evolution, it may be allowable to summarize here a few of those objections to the natural selection theory which were supposed to be avoided by the theory of mutation.

(1) The difficulty of believing that the incipient stages of useful organs or characters can be subject to selection.

(2) The common occurrence of useless characters, including many of those by which species are distinguished from one another. Allied to this is the over-development of certain structures, which may thus become not only useless but positively harmful.

(3) The inability of selection to account for the discontinuity between species in nature. Why the gaps which are everywhere seen?

(4) The assumption that nothing qualitatively new can possibly result from the selection of quantitative grades in the development of an existing character.

(5) The experimental demonstration of the fact that the efficacy of selection, when crossing with other strains is excluded, is commonly limited to a very few generations. In many cases, indeed, a reversion to the original type is encountered as soon as selection is discontinued.

(6) In addition to such arguments as these, the mutationists were able to point to the actual occurrence of variations which appeared to conform to the required type. A vast array of such evidence was accumulated.

Those who were opposed to the mutation view, in this earlier form, could fairly reply (among other things):

(1) That the theory of sudden, fairly large changes renders even more difficult our understanding of complex, harmoniously working organ systems.

(2) That paleontology, despite the prevailing incompleteness of its records, offers much evidence for the continuity of development. What appear to be perfectly continuous series of extinct forms

have been found, in certain cases, where the conditions of preservation were particularly favorable.

(3) That existing geographic variations are largely of the continuous type. One geographic race frequently grades into another through insensible steps.

(4) That the existence of mutants, sports or freaks, within species, had long been recognized by systematic zoologists and collectors. Sometimes the same mutant type was known to crop out in a number of related species, paying no attention whatever to specific lines. The nature and mode of occurrence of these aberrations seemed to place them in a different class from the characters by which species or other natural groups were distinguished.

(5) That the results of crossing natural species are found to be quite different from the results of crossing artificial races, which differ by one or more simple characters believed to have arisen through mutation. No obvious Mendelian segregation is evident in crosses of the former class.

(6) That practically all the best-known illustrations of the phenomenon of "mutation" are of the nature of losses or abnormalities, which would tend to unfit the possessor for living in any natural environment.

This divergence of view-point in respect to evolution was paralleled by a similar divergence in respect to heredity. Mutationists, since the resurrection of Mendelism, have probably all been supporters of the view that the entire heritage of an organism consists of discrete, practically unchangeable unit factors, which combine and separate in biparental reproduction, according to the laws of chance, without affecting one another.

Those who opposed the mutation standpoint for the most part minimized the stability of the hereditary units, claiming that the latter were subject to quantitative changes or to mutual contamination in crosses, or even that inheritance of the Mendelian sort (dependent upon genes) represented but a fraction of the entire process of inheritance.

I think it may fairly be said that the truth, as now generally accepted, is intermediate between the extreme positions stated above. The outcome of this controversy has been something of a compromise as regards the really essential points at issue, though I am not sure that one side, at least, would concede this to be true. The mutationists were probably more nearly correct, so far as fundamental principles were concerned. But they were, at the outset, decidedly reckless in the application of these principles, calling into question facts which did not, at the time, seem reconcilable with them.

It now seems likely that those who have argued for the existence of discrete units, both of evolution and heredity, are correct in principle. Chemists have their molecules and atoms, and physicists their positive and negative electrons and their quanta of energy. Not only is the theory of abruptly mutating genes in keeping with the present trend of thought in the physical sciences, but it has in its favor a large array of experimental evidence.

On the other hand, the proponents of both mutationism and Mendelism have had to recast their conceptions to such an extent that they have conceded nearly all which is required for the purposes of Darwinian selection, and have left the outlook both for taxonomy and phylogeny virtually undisturbed. Mutations are no longer large, abrupt affairs, affecting in a visible way many parts of the organism. The great majority of them are vanishingly small. The "continuous" or "fluctuating" variabil-

ity of every part of every organism is no more to be rejected as material upon which selection may work. It is now known to be due to transmissible or genetic differences, as well as to modifications imposed by the environment, during the single lifetime.

Different grades in the size of a given part, or the degree of development of a given character, so far as these are hereditary, are now attributed to the influence of numerous genetic factors, each small in effect when taken singly, but cumulative in their action. After a cross between two species or races, these factors segregate according to the laws of chance, giving rise to every possible combination, but with little probability of the return of either parent type in its pure form.

Moreover, the stability and discreteness of the single gene, or genetic factor, has had to undergo considerable curtailment. Modern research has shown that certain genes (*e.g.*, those responsible for eye color in *Drosophila*) are subject to whole series of finely graded quantitative changes. The case for discontinuity is saved by the assumption that there is a definite number of such possible grades, corresponding, perhaps, to the number of possible molecular combinations.

Furthermore, the German geneticist Goldschmidt, from extensive studies of heredity and sex in Lepidoptera, has come to the conclusion that the same genes (or rather corresponding genes), in related species or races, may have different quantitative values or potencies.

Arguing from such facts as the foregoing, some biologists have very recently begun to emulate the physicists by calling into being a system of secondary genes or "genomeres," into which the mind's eye may resolve our hitherto recognized hereditary factors.

With this revised conception of the nature of the unit factors of heredity, it is evident that the type of hereditary variation available for the operation of selection has likewise undergone an extensive revision. We hear much less said of the survival or elimination of a *species,* the latter having first sprung into existence, full-fledged, through a single mutation. Rather is a species believed to be commonly built up through the accumulation of a large number of slight, independent mutations. Even two closely related geographic races of mice, if we can depend upon the evidence of hybridization experiments, differ by a considerable number of hereditary factors, each due, presumably, to an independent mutative change. Thus the rôle of selection has been not merely to determine which ready-made species shall become established as members of our fauna and flora. This or some other directive agency has been necessary throughout the entire process of the differentiation of one form from another.

Furthermore, one may be a consistent mutationist of the modern school, and yet believe that many species arise without any immediate participation of the process of mutation at all. Recent discussions in the field of philosophical biology have stressed the importance of a principle which, although simple and readily intelligible, had been largely overlooked by earlier writers. I refer to the principle now so frequently discussed under the name of "creative synthesis" or "emergent evolution," or by some other name. This is nothing more than a full recognition of the fact that entirely new qualities may be the outcome of new combinations of existing elements.

Within every natural population there is much genetic diversity. Let us grant that differences between homologous genetic factors or genes have been due,

in the first instance, to the process of mutation. But the almost infinite diversity of the combinations of these factors is due to the continual process of mixing and unmixing which is the essence of sexual reproduction. Far-reaching changes may thus result from selecting and perpetuating certain ones among these genetic combinations and eliminating others. Indeed, there is an active group of biologists, headed by the Dutch geneticist Lotsy, who attribute all evolution to this process of recombining existing factors, and who question or deny the modification of factors or the origin of new ones. Without going to such lengths as do these writers, we may concede that factorial recombinations, following crosses between genetically different individuals, have probably played a far greater rôle in evolution than has commonly been assigned to them. It is likely that many, perhaps most, of the novelties which are carelessly called "mutations" owe their origin to this cause.

How then, it may be asked, does up-to-date mutation differ from the type of variation which Darwin believed to furnish the basis for his theory of natural selection? The two certainly differ much less than the original mutationists supposed. But are there no differences left? Has all the controversy of the last quarter century left this question exactly where it stood? This is hardly the case. We now realize far better than Darwin did that there are two sharply contrasted classes of variations. To the one class belong the non-hereditary variations which, it is commonly assumed, are all due to the action of the environment, broadly speaking, upon the individual. To the other class belong the hereditary variations or "mutations." The latter term has been commonly retained, even though the point of view of those responsible for this name has been largely abandoned. Mutation, according to current usage, is nothing more than hereditary variation, regardless of magnitude. It may be defined as hereditary (transmissible) modification of the germinal substance; or since any actual modification of the germinal substance is presumed to be hereditary, the latter word may be omitted from the definition. Conversely, any modification of the germinal substance, however produced, would by definition be a mutation.

Another advance over the selection view, as conceived by Darwin, is a clearer realization of the limitations of selection, in producing continuous change in a given direction. The great majority of experiments in this field have shown that the effects of selection, while at first they may be rapid, soon come to an end. A level is reached in the character dealt with at which it ceases to advance, at least with any regularity or certainty. This situation is now explained on the basis already indicated, namely, that we have to do with a sorting process, by means of which particular genetic combinations are separated out from a mixed population and perpetuated. In the course of this process no new elements commonly appear upon the scene, though new combinations of previously existing elements may give rise to strikingly new qualities. After the sorting process has been brought to an end, no further change is possible, in inbred stock at least, without the advent of further mutations; in other words some of the existing factors must undergo change. But this is a rare phenomenon and may not occur in the course of a short-time experiment. Needless to say, new genetic combinations may be introduced at any stage by crossing with other strains, but changes so produced are to be ascribed to hybridization rather than to selection.

It can hardly be disputed that this revised version of mutationism, with its minutely graded series of independent genetic changes, is subject to most of the objections which were brought against natural selection in its Darwinian form, and which were supposed to be avoided by the original mutationism of the saltatory type; for example, the difficulty of explaining the pre-useful stages of useful structures, or the commonly present discontinuity between the species of our taxonomists. These difficulties regain all their former force so soon as we base the process of evolution upon the accumulation of scarcely perceptible differences, all quite independent of one another. It would seem fairly obvious that we can not retain the advantages of a saltation theory of evolution while contending, in the same breath, that the mutations which furnish the raw materials for the evolutionary process are for the most part insignificantly small.

It is surprising to find traces of an incomplete adjustment between the older and newer view-points in the writings of one who has led the way in the detection and analysis of minute mutations, and whose polemical writings have had much to do with convincing biologists in general of the factorial basis underlying quantitative variability. Morgan's volume, "Evolution and Genetics" (1925), contains a lucid and interesting exposition of his more recent point of view regarding these questions, while retaining certain of his earlier modes of expression concerning the rôle of discontinuous variation in evolution.

How else than as an argument for evolution through large steps can the following utterance be construed? "Suppose that evolution 'in the open' had taken place in the same way, by means of *discontinuous* variation. What value then would the evidence from comparative anatomy have in so far as it is based on a continuous series of variants of any organ?"[1]

Morgan had just been discussing various mutations in wing length and other characters in *Drosophila*. Some of the former have resulted in dwarfing the wings to various degrees, down to the complete loss of these appendages. But despite the fact that we are able to arrange these abnormalities in an almost complete series as regards size, "the order in which these mutations occurred bears no relation to their size; each originated independently from the wild type." This discussion leads to his query regarding the evidence from comparative anatomy.

To this query of his I think we may reply as follows, and I venture to believe that the Morgan of 1929 would scarcely dissent: Our ability to pick out forms which may be arranged in a continuous series manifestly does not in every case prove that this series represents the actual course of descent. But unless we are prepared to admit that such differences as those between the larger subdivisions of the animal kingdom have arisen discontinuously, we are fully justified in holding that gradations in the degree of development of a character are frequently important and often quite reliable indications of the direction of evolution. And this is particularly true where, as is commonly the case, several different characters have undergone simultaneous change.

Morgan's own use of the classical case of the reduction of digits in the horse shows that he has no thought of the modern one-toed condition having arisen as a single mutation from the original five-toed condition. But if not, then various intermediate stages must have occurred in the past, and the testimony

[1] "Evolution and Genetics," p. 22. (Unmodified from "A Critique of the Theory of Evolution," 1916, p. 18.)

of paleontologists points strongly to the conclusion that the right stages occurred at the right time, historically speaking. Is it, therefore, fair to say that the degree of discontinuity which seems probable in the light of modern genetics invalidates to any great extent the testimony of comparative anatomy to conclusions regarding phylogeny? We may cite Morgan's own words in reply:

> This argument for rejecting extreme or monstrous forms seems to us to-day as valid as it did to Darwin, but we now recognize that sports are only extreme types of mutation, and that even the smallest changes that add to or subtract from a part in the smallest measurable degree may also arise by mutation. We identify these smaller mutational changes as the most probable variants that make a theory of evolution possible.[3]

The data of present-day genetics are certainly in no way inconsistent with the belief that the transformation from one species to another has commonly involved no greater break in continuity than we may now observe between one individual and another within the same species. Can any positive evidence for such a belief be offered? The evidence which I shall briefly cite falls under two heads: (1) genetic, (2) geographic. Let us consider these in the order named.

According to the currently accepted Mendelian interpretation, the mutation of a single gene or factor results in a variation which is allelomorphic (alternative) to the wild type, and which gives, when mated to the latter, the simple 3:1 ratio. When, on the contrary, the difference between two races is such that, if crossed, a blended or intermediate condition results, out of which the parental types can not be recovered, or only with difficulty, we must attribute this difference to changes in a number of genes, in other words, to a number of independent mutations.

[3] *Op. cit.*, p. 130.

Now it happens that not a single case has been reported, so far as I know, in which two taxonomic species have been crossed and have been found to differ by a single pair of Mendelian factors. In other words, not a single case is known in which one species has arisen from another by a single mutation. But the case is vastly stronger than this. Two species commonly differ from one another in a considerable number of visible and measurable characters, relating to various parts of the body. In most cases where the hybridization test has been made, not only are these various characters inherited for the most part independently of one another, but each of them, taken singly, conforms to the multiple factor scheme. In very few instances does any one of the specific differences behave in heredity as if it had resulted from a single factor mutation.

In the course of my own breeding experiments, I have hybridized forms more closely related to one another than are most species. But even these geographic races differ from one another in every instance by a number of different characters, while each character, as in the case of species, is certainly dependent upon more than one Mendelian factor. Thus, if the mutation view is correct, it has required quite a series of mutations to bring about the comparatively slight differences between two adjacent geographic races. (I must repeat that the actual process of mutation did not necessarily occur at the time that the newer race became differentiated. There may have been merely a reassortment of existing genetic factors by some form of selection.)

The second line of evidence on which I rely is that of geographic variation. The student of this field knows that graded series occur in space, not occasionally but frequently, and that these

are correlated in many cases with environmental gradients.[3] In some cases, the conclusion seems unavoidable that the series in question gives us an actual picture of the steps by which one of the extremes became differentiated from the other. That there is no essential difference between such racial differences and those which distinguish "good" Linnean species will be questioned by few who are acquainted with the facts. Whether two forms be regarded as distinct species or merely as subspecies is largely a matter of convention. It seems highly probable that the formation of these geographic races or subspecies represents one among the various modes in which the divergence of species and even larger categories of living beings has had its inception.

Let us, then, return to the question with which we started: Is the process of evolution continuous or discontinuous? In my opinion, the correct answer to this question is much the same as that to the question: Is matter continuous or discontinuous? In both cases, we have to do with a sensible continuity, based upon an underlying discontinuity. I have already indicated my belief that the transition from one species to another has commonly involved no greater breaks in continuity than we may now observe between one individual and another within the same species. The idea that not only widely distinct species, but new genera, families and even higher categories have come into existence suddenly may relieve us of the embarrassment of not finding intermediate forms, but it is not supported by a single direct observation. The suggestion of Lotsy[4] that new classes and phyla have originated abruptly from recombinations of factors brought about by the crossing of species does not seem to have a much firmer scientific foundation than that of Geoffroy St. Hilaire regarding the hatching of the original bird from the egg of a reptile. Neither Darwinian selection nor Lamarckism nor both combined involves us in assumptions half as incredible.

[3] In a recent paper (Proceedings of the National Academy of Sciences, February, 1929) I have discussed an illustrative case in which seven different grades were found in respect to certain characters. While the full meaning of this case is still far from clear, the evidence is all against the supposition that the extremes (or even any two contiguous populations) were differentiated from one another through a single mutation.

[4] "Evolution by Means of Hybridization," 1916 (particularly pp. 119, 135, 147). I need hardly say that it is far from my intention to belittle Lotsy's extensive and important contributions to the literature of evolution.

GROWTH CURVES OF INSTITUTIONS

By Dr. F. STUART CHAPIN

SOCIAL SCIENCE ABSTRACTS, NEW YORK

I. Setting and Importance of the Problem

Whether our special interest be economic geology, poultry husbandry, mathematical physics or the economics of advertising, our lives are inextricably interwoven with social institutions which, at the same time that they hem us in, also serve as channels for self-expression. Distinguished scholars whose connection with some great university seems secure are suddenly cast into academic outer darkness because by some act they have transgressed the mores of the family institution. Men of mediocre ability often attain amazing heights of power and influence when they become the spokesmen of a political institution whose secret inner passages they have learned and to whose law of being they conform. Experiences of this sort have given food for the thought that institutions are permanent and massive elemental things. Radicals rage against them, moralists extol them, philosophers weigh them in the scales of verbal dialectic. The important question is—can we measure them? If we can measure them a new avenue of understanding is opened up and questions of the stability, permanence or change in social institutions may be answered in terms objective rather than subjective.

The following paper outlines the procedure and results of a preliminary attack on the problem of measuring changes in social institutions.

II. Research Method of Attack

The first step in scientific work is to set up a working hypothesis. We therefore state our working hypothesis thus: Social institutions pass through a cycle of change in structure and function.

Inasmuch as the unit of observation is an important consideration in scientific research we have selected for analysis four political institutions representing two different sorts of units.

Our unit of observation selected is a social invention. Mechanical inventions are such familiar and tangible objects as the automobile, telephone, radio, etc. Social inventions by comparison are not as generally recognized but they exist in great numbers; examples are the stock exchange, juvenile court, commission plan of city government, city manager plan, non-partisan ballot and many other innovations that have broken down the sway of hoary custom and ancient tradition. Our procedure in studying these institutions is to count the units of observation that occur in equal intervals of time for the same area. Inasmuch as we have as yet no uniform units of measurement or, to express the situation a little differently, since we have no means of expressing changes in the phenomena of observation in terms of the standardized units of an external criterion, we must needs resort to the expedient of counting the number of similar things which occur in equal intervals of time. We therefore examine the constitution or charter and the legislative record or ordinances, and count the number of new commissions, bureaus, departments or activities that are added each year. This is the first step toward eventual measurement and at least has the merit of describing the phenomena

in terms of verifiable facts rather than of evaluating them in terms of opinion.

III. Results

New animal organisms begin with the fusion of the female ovum and the male sperm. New social and political institutions appear to begin with the fusion of old ideas into a new mental pattern or what is popularly known as invention. In 1900 a new form of municipal government was invented[1] (at Galveston, Texas) and became known as the commission plan. Since 1900 it has gone through a cycle of growth and decline. When we plot, year by year, the number of communities that adopted the new plan we find that this plot takes the form of a roughly symmetrical frequency curve.[2] When the yearly increments are cumulated we find a growth curve similar to the growth curves that Pearl and other scientists have found for biological organisms. In this case, however, the units of growth are towns and cities adopting the plan. Thus our growth curve for the commission plan is a population growth curve in which the unit of count is a town or city and not a human individual. We have found similarly that the city manager plan, an offshoot of the commission plan, follows the same principle of growth.

These illustrations of the principle of the organic growth of social institutions are suggestive but do not offer convincing evidence because the growth phenomena consist in the spread of the new pattern over an area by diffusion and not by increase and elaboration of parts within one whole. Fortunately our research supplies evidence which meets this test. We have analyzed the changes that have occurred in the structure and function of two other political institutions each of which is an institutional entity in itself and may be regarded as a functional unit in American political life. We have taken the government of the city of Detroit[3] and the government of the state of Minnesota.[4] Our data for the city of Detroit cover the period beginning in 1824, and for the state of Minnesota beginning in 1858. Unlike the two former instances the increases of units at regular time intervals do not in the cases of Detroit and Minnesota follow a frequency cycle curve. Possibly we are dealing with phenomena having a longer life span, or perhaps another principle operates. When, however, increments of change are cumulated we find that these political structures follow growth curves similar to the first halves of the growth curves of the commission and city manager plans. The first point of inflection of the normal growth curve is passed but the second point of inflection is not attained. Consequently we can not summarize the phenomena by a Gompertz or a Pearl-Reed curve but find that a parabola is the best fit.[5]

Our data for Detroit and Minnesota consist of units less homogeneous than in the case of the commission and city manager data, because different functions and elaborations are added together to find the ordinates of the growth curves. On the other hand, we are dealing in each case with the growth of one political institution having real unity and not with the diffusion of a pattern to similar units of different size spread over an area. Consequently our study of growth of the institution of government in Detroit and Minnesota concerns phenomena

[1] E. S. Bradford, "Commission Government in American Cities," New York, 1916, pp. 3–23.

[2] F. S. Chapin, "Cultural Change," New York, 1928, p. 370.

[3] Upson, "The Growth of the City," and Chapin, "Cultural Change," pp. 361–368.

[4] M. B. Lambie, "Administration of the State of Minnesota," 1924, p. 6.

[5] F. S. Chapin, "Cultural Change," pp. 377–379.

similar to those considered in studies of growth in bodily weight of animal organisms. For this reason these last-mentioned studies are more significant evidence of the existence of a principle of growth of social institutions.

IV. Interpretations and Results

Why do institutions grow like organisms? An adult animal organism which began as a single cell attains its growth as the result of cell division and specialization. By contrast a social institution may begin as an invention—a mental pattern of a social relationship of interacting human organisms. These interacting human beings exhibit attitudes toward one another and their overt behavior gets conventionalized by interstimulation and response into such explicit social patterns as folk-ways and mores. Behavior of an emotional sort gets conditioned to such symbols as the flag or idol, depending upon whether it is a political or religious institution that concerns us. Thus it is that symbolic culture traits appear. Creature wants are met by the construction of dwellings, buildings and furnishing tools and equipment of various sorts. Thus it is that material culture traits are provided. Finally men commit to oral tradition or set down in writing their creeds, charters, constitutions or agreements and thus it happens that there are stored externally to the minds that created them the rules of relationship which constitute the underlying pattern of the institution. If we summarize our analysis of the institution in four terms: human attitudes, symbolic objects, useful objects and oral or written descriptions of the interrelationships of these three things, then it is not difficult to see why and how the social institution grows. It grows because it is the most complex form of human accommodation to a changing world. Population increases, gains by immigration, losses from wars and climatic disturbances and other events necessitate a readjustment of the original pattern of human relationship. As a consequence new symbols are invented, mechanical innovations appear and relationships become more complex. New functions develop and structure and relationship must be readjusted to make old institutions continue to work. To summarize, we may say that the social institution consists of a network of complicated interrelationships of psychological dispositions and material traits of cultural significance.

The foregoing interpretation may sound abstruse. Let us offer another interpretation of a less abstruse sort. This interpretation necessitates reference to concrete material not part of the data of observation of our immediate study but material entirely relevant to the problem. We have studied the poor law legislation of England, Massachusetts, Wisconsin and Minnesota and find that in every case the same cycle of development occurs.[6] This cycle is as follows: first, the original poor law practice is enforced until exceptions accumulate; second, many variations from it are experimented with until the situation becomes so chaotic that, third, the whole mass of laws is integrated into a code which embodies the general principles. Reverting now to the case of growth of institutional structure, we find that after the initial constitution or charter is written (the original invention) there follows a period in which modifications, additions to or amplifications of the original structure take place. This is the period of rapid growth when the curve has passed the point of inflection and shoots up suddenly. This period corresponds to the phase of experimentation in poor relief legislation. Then

[6] F. S. Chapin, "Cultural Change," Chapter VIII.

comes the period of integration when the rate of growth diminishes. This period is illustrated by the consolidations that have been effected in many of our state governments, consolidations that simplify an overcomplex structure. We have recently described this principle and called it a societal reaction pattern.[7] The principle is mentioned here because it seems to offer an interpretation in terms of social psychology for the growth tendency of social institutions described in the present paper.

In conclusion, interpretation of these results can be merely provisional, for the cases studied are too few to constitute even representative samples. This qualification, however, does not invalidate the conclusion that the working hypothesis stated at the outset has been justified. Our study shows that the total changes of four political institutions for a period of years may be described as a growth tendency not unlike the growth principle of animal organisms. Whether further study of this phenomenon of social change will lead to successful formulation of a law of social growth it is premature to say. At any rate, the results of this preliminary investigation seem to the writer to be justification for more extensive research into the field by a number of independent workers. Moreover, the interest aroused by such recent books as Spengler's "The Decline of the West" and Beard's "Whither Civilization?" encourages the belief that future investigations may be made following the more concrete procedure used in the present study. If this be the case we will gradually accumulate a systematic knowledge which may lead to the discovery of the natural laws governing the life history of social institutions. When this point is attained it will be only one step more to predict growth and bring social institutions within the range of rational social control.

[7] *Ibid.*

TOOLS OF PROGRESS

By Dr. RALPH E. DANFORTH
CHESTERFIELD, MASS.

SCIENCE is the Creator's chest of tools. Human progress is man's learning to use these tools.

Large masses of folk are suspicious of the very word *science*. Call it *modern* science, and they suffer emotional chills and fever. They have not even seen the truth that science and knowledge are one.

Many, realizing that *they* at least have not consciously done anything to advance knowledge, are very suspicious of it as of something strange, foreign to themselves, and as such possibly a trouble-breeder. In fact, they may have heard it stated that it would weaken the foundations of the home, undermine faith, or in some way or combination of ways prove hurtful to their vital complex.

If science and knowledge are one, modern science is the recent advance of knowledge. The oldest and most sacred of knowledge was one time modern. Modern science of to-day will some time be old and sacred. If by that time people's nerves have not steadied, they will suffer emotional chills and fever when the steady increase of knowledge will seem to them to threaten that which, new to us *now,* will *then* seem old and fundamental, having been built into the very foundations of human life.

The term *science* is becoming so elastic and all-inclusive that we would not be far amiss were we to say that all truth newly gained to-day could be called science. Science has also to do with the application of truth, as well as its substance.

The universe was created long ago, is still in process of creation and may, possibly, always be in process of creation. It is no longer safe for the scientific man to say that anything can not be. We are learning that all things are possible.

The tools with which the Creator made the universe and the materials of which he made it are neatly arranged in the great tool-chest, which is the vast universe itself. Man opens the chest, or more properly opens his eyes and his mind, for the chest stands always open to those who will see, and beholds the structure and the forces which are at work therein. Familiarizing himself with the chemical elements, relatively few in number, of which the whole universe is made, with their combinations and some of their endless possibilities, man at once begins to imitate some of the compounds which the Creator had already made, and also to make new combinations, suited to new purposes of his own. "Sacrilegious!" cries the man in the street, although he may have just come from a clinic where a recently invented compound was injected into him in the treatment of an old disease, and with the word still on his lips he may board a bus, in the engine and other structures of which many new combinations of metals and forces are operative. He then goes home, uses his telephone, in which other new combinations of matter and force are functioning beautifully, to call upon his friend and tell him that modern science is making the world altogether too materialistic. This is human progress: learning to know and use the tools of the Creator. The scientist feels that the Creator intends that he should do this.

Chemical elements and their numerous

compounds, physical force, vital energy and the yet more mysterious realities of intellect, affection and soul, these are at once the tools and fabric used in shaping the universe. These are the tools and fabric which man is learning to use as he begins to understand the cooperative part which his Maker, in whose image he was made, intends him to take in the divine plan.

The tools of progress were used in shaping man as well as the rest of the universe. They are being used in shaping man to-day. They will be used in shaping man in the future. They shape his mind as well as his body, and the heart or soul of him as well as his mind.

Man himself, in cooperation with the Great Originator, may have a hand in the making and fashioning of the human race. The real difference between the statesman and the simple politician is that one thinks constructively for the good of man while the other can not see past the edge of his pocket. The measure of the statesman is his creative reach. He must have vision, heart and the genius of achievement.

All additions to the sum of truth which we possess place more tools and materials in the hands of human benefactors, whether they be statesmen, scientists, teachers or just plain mothers.

These new truths, tools or powers are popularly styled to-day modern science. And what can this new light of knowledge hurt?

What can modern science hurt? Human errors shrivel in the white light of knowledge as lint in a flame. Follies too will be hurt, for they flee the light of truth as dry leaves flee the autumn gale.

Religion, will it be hurt? The foundations of faith, will they be shaken?

Real worth in religion will never suffer from the truth, be that light of truth new or old. Intrinsic value, the true gold of faith, is not hurt by the acid test.

The flood of light, ever swelling, every moment more intense, while showing up error and superstition, will give new growth to the true "trees of righteousness," and new beauty to the flowers of faith and love. Purely artificial and dogmatic elements of ecclesiasticism may suffer, but the resulting health of the religion within the heart will justify the sacrifice many times over. The eternal heart of religion will grow prodigiously as the blankets which smother it are peeled off and consumed. That which has abiding value will increase; the goldbricks be exposed.

But modern science rapidly swells the flood of light. This growing light of truth and knowledge and power is daily adding to human comfort. Not alone the comfort of body but comfort for mind and soul increase as truth increases. In fact the main function of truth is to increase comfort and well-being. Did not the great Teacher say he would send the "Comforter" who is "the Spirit of truth" and "will guide you into all truth."

If religion is to be benefited by the ever-brightening rays of truth, what *will* modern science hurt?

Modern science will hurt whatever the true tools of progress will injure; whatever stands athwart the fundamental plan of the universe.

It seems as though the continued approach unto all truth would hurt many things. A number of human industries will be hurt by the increase of knowledge. In this country legalized liquor trade has already been hurt. The chances of its speedy recovery seem smaller than the chance of the spread of the same injury to other leading countries. A number of other industries, which increasing knowledge may demonstrate to be destructive rather than beneficial to the best interests of man, will be seriously hurt if not actually destroyed.

The isolation of many peoples will very soon be seriously hurt by the rapidly spreading light of knowledge and communications. With the destruction of isolation many long-cherished ideas and personal habits of the erstwhile isolated ones will be hurt unto death. Like cockroaches beneath an over-turned box, fleeing before a flood of light, the deep-seated errors of benighted folk will scuttle into the dark cracks and crannies of oblivion.

Languages, now counted by hundreds, will be hurt and reduced to an irreducible minimum. The thought of mankind will then flow freely around the globe, and be the property of whoever has ears to hear. New discoveries, inventions, facts—new truth in any form, will encircle the earth at lightning speed, a light to enlighten all Jews and Gentiles who have mind enough to comprehend it and the will to absorb it.

Mental habits and bodily habits of persons right at home, as well as those of the benighted in isolated lands, will be hurt to the extent of being supplanted by better habits, when the blast of larger truth glares with spot-light intensity upon them. Many pet follies, now perfectly legal and even generally cultivated, will wither in the sunlight of the full truth. Seeing through a glass, darkly, permits many customs which a brighter light would show to be ugly rather than desirable. In the gloom below the jungle are many growths which can not endure the full light of the sun.

But all this hurt from modern science will react to our benefit. Only those who are so completely obnoxious that everything in them will be hurt by the light can really be counted sufferers. All others will rejoice in the healing beams of increased knowledge, and be glad of the changes it brings about in their thought and habit and health. Their new ways will mean new powers, more real and lasting wealth and new joys.

Modern science will hurt war. Already some serious blows have been dealt that common foe of mankind. Our old knowledge will help valiantly in destroying war, but we may need yet new light before it is completely put down.

With the increase of knowledge national boundaries will cause less concern. Patriotism and liberty will take on new meanings among the many republics and provinces and dominions. Instead of shouting loudly and wildly for *independence* and *liberty* the concept of the welfare of the individual, as something of more substantial worth, will gradually replace in men's minds what is after all but the ghost of a panacea. There is no such thing as an absolutely independent nation. Probably there never will be, unless it includes the whole earth. In traveling among little countries I have observed that it is the citizens of the countries bestowing the least real benefit upon them who do the most orating about *patriotism,* and they also do the most fighting. This orating about patriotism, and this fighting, together with drinking and gambling, are the breath of life to many in whom sentimentality exists in gigantic proportions and the practical sense appears to be altogether omitted. Modern science never has been forwarded by such folk, neither will they ever let other people apply it to their benefit if they can fight it off.

In the far East there are millions who loathe "western civilization." There are faults in the westerners, but these should not be attributed to civilization. Countless brains are too small ever to be able to discern the good from the bad. There is no alternative but for them to die in their ignorance.

Finally, brethren, what do you think of a minister who preaches science instead of religion in his church? I think him a fool, though he may be a fool who

has seen a gleam of real light. The church will never be able to vie with other institutions as a center of scientific information. And the minister usually half murders his science, unless by chance he has spent years at practical scientific work in the laboratories supplementing his text-book studies. And even were he a highly trained scientist standing in the front rank of the world of science he could not make a science take the place of true religion in the church. Modern science will never be able to hurt true religion except in those who substitute it for religion. True human progress lies in the cooperation of science and religion, not in substitution. Religion needs vitally all the new knowledge it can get, in order to grow; and if it does not grow it dies. This is the gleam of truth which the science-preaching pulpiteer espies. But his vision is very fragmentary, ruinously so. But the world of science needs true religion just as much. Without an eternal and righteous and loving spirit in his heart the scientist is little better than the clay with which he works, or a nut without a kernel. The two must be found together if anything good is to grow out of it. The future progress and happiness of man depends upon the united effort of religion and science.

What can modern science hurt? Everything that leaves it icily alone, and every one who makes it all in all and worships it as an idol. Our minds must be big enough to exceed the minds of the revolutionists who holler *liberty* when they have not the least idea what they are talking about, and the minds of those who would trample western civilization under foot as worse than worthless. There are small-minded men at home, but fortunately fewer relatively than in some other places on earth.

THE PROGRESS OF SCIENCE

THE TWENTY-FIFTH ANNIVERSARY OF THE CARNEGIE INSTITUTION OF WASHINGTON

On May 31, at Cold Spring Harbor, Long Island, the Department of Genetics of the Carnegie Institution of Washington was "at home" to invited guests. The reception was held in celebration of the conclusion of the first quarter century of the work of the institution founded by Andrew Carnegie for the conduct of research. Representatives of some sixty institutions, organizations and departments of research were among the two hundred or more guests who accepted the invitations of the president and trustees of the institution.

At eleven o'clock the guests assembled in a tent erected on the grounds. Addresses were given by General John J. Carty, representing the trustees; by Dr. E. G. Conklin, head of the department of biology, Princeton University, representing scientific men, and by Dr. John C. Merriam, president of the Carnegie Institution, representing the staff. Dr. Henry S. Pritchett, vice-chairman of the board of trustees, presided.

The remainder of the day was spent in talking with the investigators and in inspecting the exhibits which the staff had prepared to illustrate their methods of investigation and somewhat of the results that have been obtained. These exhibits were open to public inspection on June 1 and 2.

The Department of Genetics is one of the major departments of the Carnegie Institution of Washington. It was organized in 1904 and called the Station for Experimental Evolution.

Three other major activities were initiated at the same time: the Marine Biological Laboratory at Dry Tortugas, Gulf of Mexico; the Desert Botanical Laboratory (now a section of the Division of Plant Biology) at Tucson, Arizona; and the Mount Wilson Observatory at Pasadena, California. These four stations were among the first to be established by the Trustees of Carnegie Institution; they thus mark the inauguration of major research activities begun twenty-five years ago.

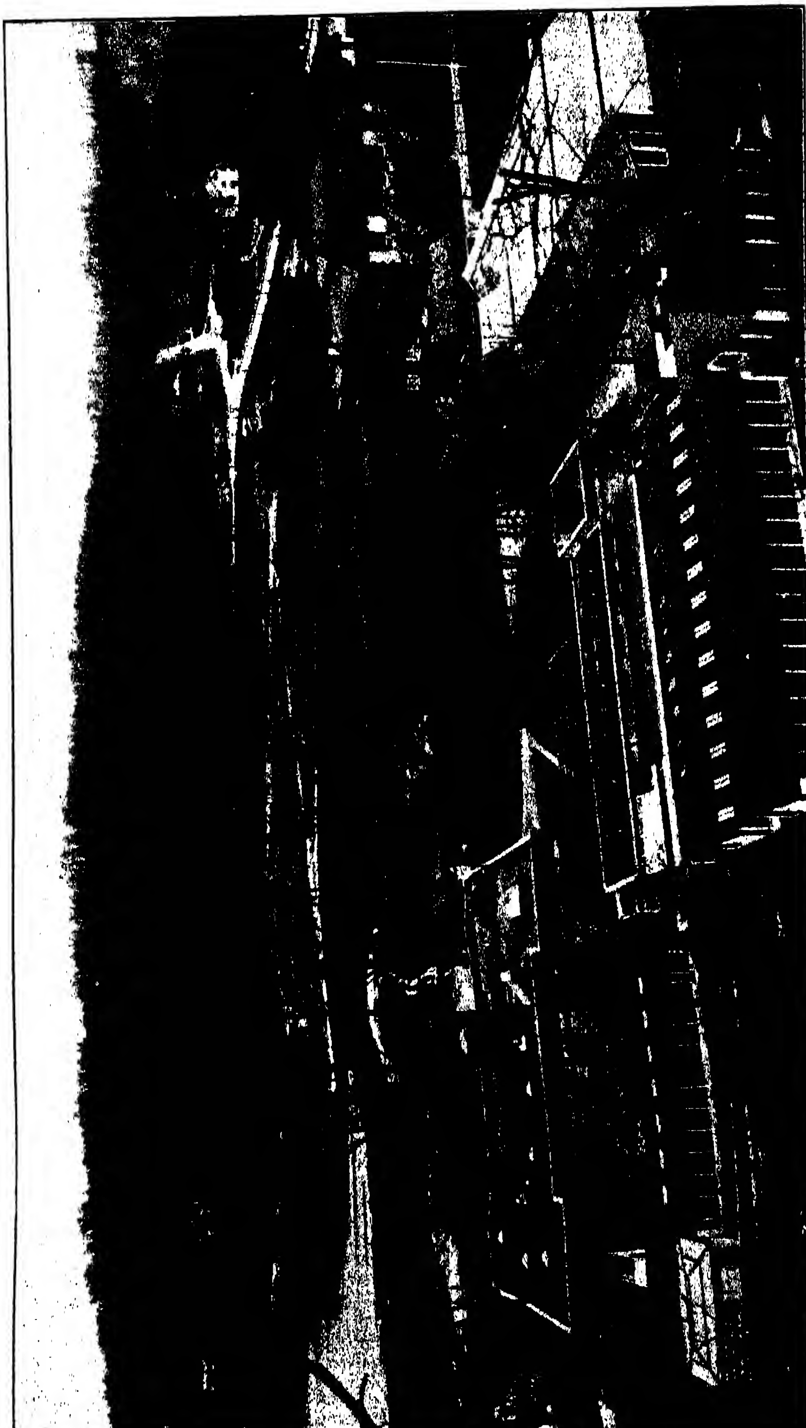
In the present organization of Carnegie Institution the major researches are grouped in ten departments or divisions with which are associated many specific investigations not of departmental type. Research is being conducted on fundamental problems in the fields of embryology, genetics and eugenics, nutrition and vitamin chemistry, plant biology, marine biology, geophysics, seismology, terrestrial magnetism, astronomy and early American history, including archeology and historical research.

The institution is also attempting to extend the usefulness of its own data of research, to increase mutual understanding among its own investigators, and to promote public appreciation of its work by holding each year, at the Administration Building in Washington, a series of lectures on topics relating to its work and an exhibition illustrating current results of its researches. For the same reasons the present exhibition has been arranged.

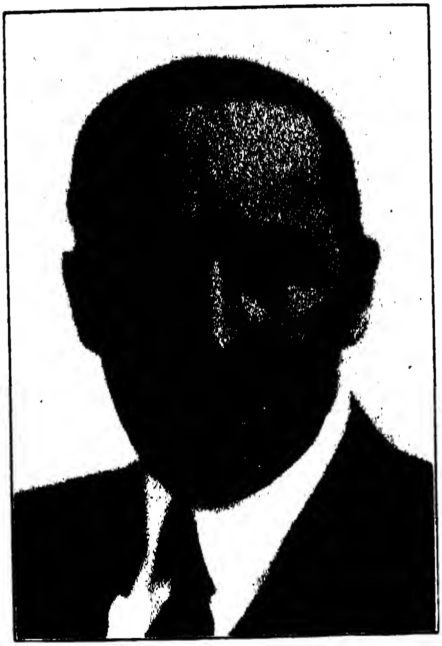
Almost to the day, twenty-five years ago, the formal opening of what is now the Department of Genetics took place at Cold Spring Harbor, Long Island.

Two years before, Dr. Charles B. Davenport, then of the Zoological Laboratory of Chicago, had submitted a plan of organization which was adopted. Upon invitation of the trustees, Dr. Davenport assumed the directorship, which office he has held to this day.

In 1910, Mrs. E. H. Harriman founded the Eugenics Record Office on an 80-acre tract nearby and arranged



THE COLD SPRING HARBOR LABORATORY OF THE CARNEGIE INSTITUTION

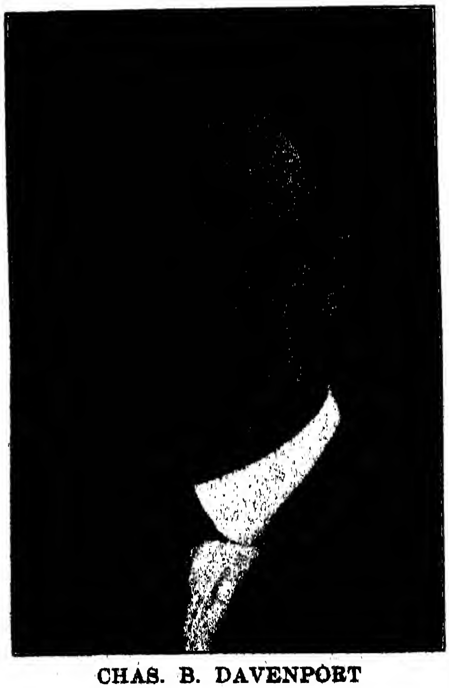


JOHN C. MERRIAM
PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

for a staff for the study of problems relating to human heredity. Eight years later Mrs. Harriman transferred the office and farm to Carnegie Institution of Washington and provided an endowment toward the maintenance of investigation. In 1921 a reorganization was effected whereby the work on human heredity and that on heredity in plants and animals were combined in a Department of Genetics.

For twenty-five years the genetics staff of the Carnegie Institution has been at work in their field. By studying the hereditary material itself in the laboratory with stains and microscope and camera; by inducing a multitude of matings among plants, insects and vertebrates and studying the offspring; by making statistical studies of racing capacity in horses; and by collecting the individual and family histories of thousands of persons and analyzing them from the standpoint of hereditary traits —by these and other methods have the members of the staff sought with gratifying success to cooperate with scientists elsewhere in penetrating the secret of inheritance and of variation.

What Makes Differences in Living Things? is the problem being investigated by the Department of Genetics and related departments. Such differences range from the great ones that separate elephants from bacteria, to such subtle ones as distinguish "identical" twins. Two paradoxical tendencies are illustrated by these extremes: the conservative tendency for like to beget like, and the restless tendency for life to appear in ever new forms. The full solution of the problem would explain how organic evolution takes place and what life is. Every phase of the study of life makes a contribution towards this solution. Some of the special fields that are being explored in search of solutions were illustrated by the exhibits grouped under the four divisions: Differences in chromosomes; Differences in environment; Differences in age; Differences in glands.



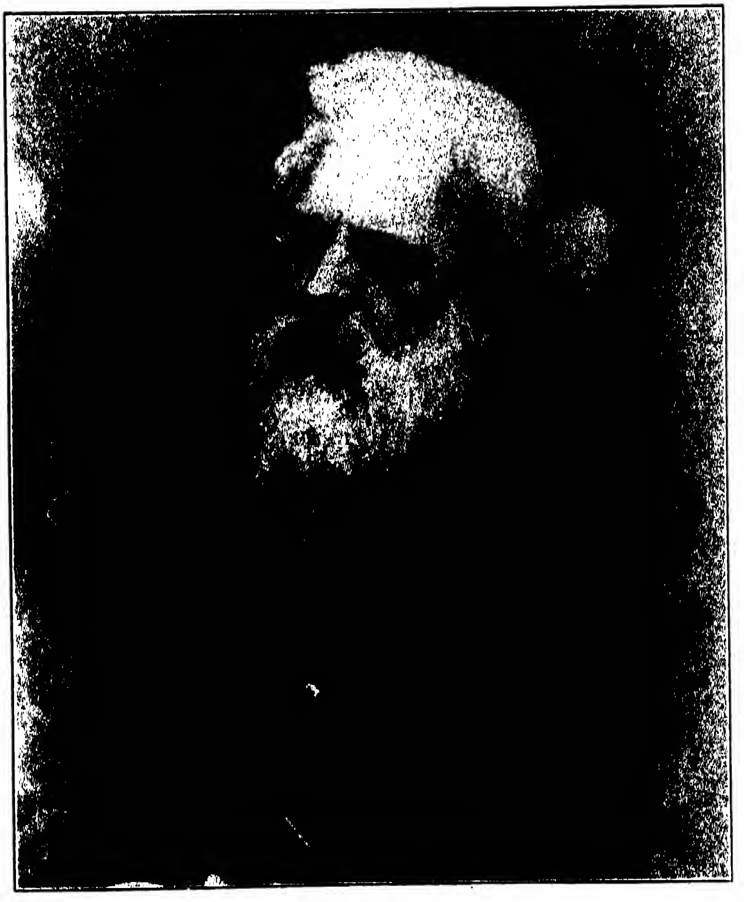
CHAS. B. DAVENPORT
DIRECTOR OF THE COLD SPRING HARBOR LABORATORY

LELAND STANFORD

BUILDER OF THE CENTRAL PACIFIC RAILWAY, UNITED STATES SENATOR AND FOUNDER OF STANFORD UNIVERSITY. THE PORTRAIT WAS PAINTED BY MEISSONIER IN 1881. THEY BECAME ACQUAINTED THROUGH THE MOTION PICTURES OF THE STANFORD HORSES. STANFORD IS HOLDING THE ALBUM OF HORSE PICTURES.

THE EARLIEST MOTION PICTURES

IN May, Stanford University held a semi-centennial celebration in commemoration of the motion picture research conducted by Leland Stanford at his Palo Alto stock farm in 1878 and 1879 with the assistance of Eadweard J. Muybridge and John D. Isaacs. It is believed that this is the first investigation to make use of consecutive instantaneous pictures and, therefore, lies at the basis of the photographic analysis of motion and also the portrayal of movement through the motion picture. Something over two thousand such pictures were taken by Muybridge. Many of those that had to do with the locomotion of the horse were later analyzed by Dr. J. D. B. Stillman, whose book, "The Horse in Motion," was published in 1882. Official delegates from the Academy of Motion Picture Arts and Sciences took part in the exercises. Tablets commemorating the Stanford-Muybridge research were unveiled, one in Memorial Court at



EADWEARD J. MUYBRIDGE

the main quadrangle of the university and the other, a duplicate, near the site of the Muybridge studio. Dr. Walter R. Miles, professor of experimental psychology at Stanford University, gave two addresses, "The Stanford-Muybridge Research on the Portrayal of Motion" and "Technique and Results of the Palo Alto Experiments." Among other addresses by scientific men and leaders in the motion picture industry was a talking picture address by the Honorable Ray Lyman Wilbur which was made possible through a portable outfit recently developed in the Bell Telephone Laboratories. This address for a specific occasion and presented in a college banquet hall marks an advance in motion pictures that is of much educational significance.

The motion picture art and industry has grown to immense proportions. One of its essential beginnings is associated with the Stanford University Campus in that Leland Stanford conceived and caused to be carried out a photographic investigation at his Palo Alto stock farm in 1878 and 1879. His interest in the locomotion of the horse caused him not only to take interest in the general analysis of the horse's stride, but he appreciated the individual differences and saw the importance of this in connection with his attempt to breed and rear the

MONUMENT COMMEMORATING THE STANFORD-MUYBRIDGE MOTION PICTURE RESEARCH

CONDUCTED IN 1878–1879, UNVEILED AT STANFORD UNIVERSITY, MAY 8, 1929. REPRESENTATIVES OF THE ACADEMY OF MOTION PICTURE ARTS AND SCIENCES IN ATTENDANCE AT THE DEDICATION: (LEFT TO RIGHT) WILLIAM C. DE MILLE, CLARA BERANGER (MRS. DE MILLE), ALEC B. FRANCIS, LOUIS B. MAYER, MRS. MAYER, MRS. DENNISON CLIFT, LOUIS H. TOLHURST, MRS. TOLHURST.

fastest horses. Mr. Stanford, desiring to make objective certain of the fleeting phenomena that he had learned through practice to perceive by eye, turned to photography. In general at this period, photographers were content if they could register waves of the sea and they were not striving for instantaneous pictures as we think of them to-day.

Mr. Muybridge, when lecturing about his animal photographs in the eighties, was fond of telling that at first he did not believe Leland Stanford's projection at all feasible. He considered that photographic technique was not up to the task of registering such rapid successions of motion as the running of a horse. The problem was conceived by Mr. Leland Stanford, who secured Muybridge as photographer and paid him for his services. Muybridge did the first work for Stanford in 1872 at Sacramento. Mr. Stanford moved from Sacramento to Palo Alto and established his stock farm here in 1876. Muybridge worked as a photographer in San Francisco. A man by the name of Larkyn, from Australia, fell in love with his wife; Muybridge shot Larkyn at the Yellow Jacket Mine near Calistoga, California, on October 18, 1874. He was arrested and lodged in jail and on December 8, 1874, the Grand Jury returned a bill against him. He was tried at Napa, California, beginning February 15, 1875, and the jury returned a verdict of "not guilty." Shortly after this he went to Central America and took many photographs relating to the coffee industry, returning to San Francisco sometime in 1876. Leland Stanford was then well established at Palo Alto and

wanted to continue his investigation of the locomotion of the horse. He got Mr. Muybridge to make some further trials in 1877. It was Stanford who suggested using *more than one camera.* He finally suggested using twenty-four cameras placed a foot apart, adopting this on the basis of the stride of the horse being as a rule somewhat less than twenty-four feet. He therefore conceived that the twenty-four cameras, a foot apart, would cover the longest stride and would give a sufficiently detailed analysis. A reflection screen, fifty feet long and fifteen feet high, built at an angle facing the south, provided a brilliant background against which to photograph the horse. Horizontal lines and vertical lines placed on this background provided the coordinates against which to measure the successive silhouettes. The exposures of the wet plates were of one thousandth second and shorter. John D. Isaacs, mechanical engineer, working in one of the shops connected with Mr. Stanford's railroad interests, was secured to develop better technical means of timing the photographic exposures in reference to the progress of the horse past the cameras. Isaacs devised electrical means of operating the shutters which materially advanced the research.

These were the first truly consecutive instantaneous pictures portraying rapid motion that were used by Mr. Stanford, Mr. Muybridge and others in the "wheel of life," zoetrope and other devices which had formerly been developed to give motion from series of drawings and from sets of posed photographs.

Stanford permitted Muybridge to copyright the photographs as he himself originally had no idea of publishing anything concerning the work. He kept Muybridge quite busily engaged during the years 1878 and 1879 and invested all in all about $40,000 in the project, sending Mr. Muybridge to Europe in 1881. Muybridge did not return to Palo Alto or San Francisco to take up photographic work again. He got into correspondence with Provost William Pepper in 1884. This correspondence resulted in his going to work at the University of Pennsylvania, where, according to the statement of Muybridge, "the Palo Alto outfit was duplicated" and in fact, in place of one battery of twenty-four cameras three batteries of twelve were used at different angles. In the meantime, dry plates had become available so that the photographic results were much better than the Palo Alto silhouettes.

The text of the tablets reads:

IN COMMEMORATION OF
THE MOTION PICTURE RESEARCH CONDUCTED IN 1878 AND 1879
AT THE PALO ALTO FARM NOW THE SITE OF STANFORD UNIVERSITY.
THIS EXTENSIVE PHOTOGRAPHIC EXPERIMENT PORTRAYING THE ATTITUDES OF MEN AND OF ANIMALS IN MOTION WAS CONCEIVED BY AND EXECUTED UNDER THE DIRECTION AND PATRONAGE OF
LELAND STANFORD

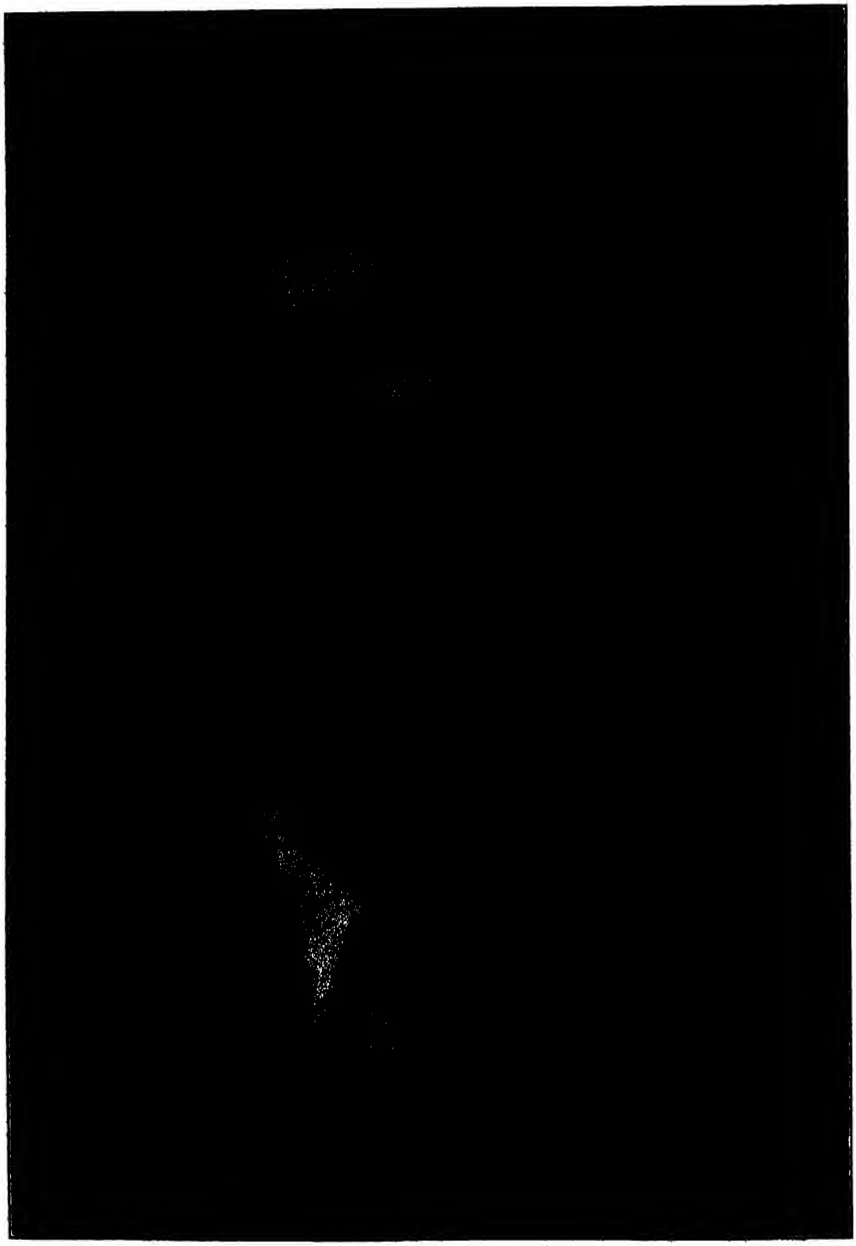
CONSECUTIVE INSTANTANEOUS EXPOSURES
WERE PROVIDED FOR BY A BATTERY OF TWENTY-FOUR CAMERAS FITTED WITH ELECTRO-SHUTTERS.

EADWEARD J. MUYBRIDGE, PHOTOGRAPHER,
CARRIED OUT THE INVESTIGATION AND SHOWED
THAT THE PHOTOGRAPHS COULD BE COMBINED IN PROJECTION TO GIVE THE TRUE APPEARANCE OF MOTION.

JOHN D. ISAACS, MECHANICAL ENGINEER,
ADVANCED THE RESEARCH BY DEVISING ELECTRICAL EQUIPMENT.

J. D. B. STILLMAN, M.D.,
ANALYZED THE PHOTOGRAPHS RELATING TO THE LOCOMOTION OF THE HORSE.

THIS TABLET ERECTED BY STANFORD UNIVERSITY, MAY 8, 1929.



ARTHUR S. LOEVENHART
PROFESSOR OF PHARMACOLOGY AND TOXICOLOGY IN THE UNIVERSITY OF WISCONSIN UNTIL HIS DEATH.

THE CAMPAIGN AGAINST CONSUMPTION

THE turning point in the Great War was when the allied forces fighting the Germans joined in a single coordinated plan of campaign under unified control by the appointment of General Foch, as commander-in-chief of all the armies. The turning point in a greater war may likewise date from the day when the allied forces fighting the germ of tuberculosis joined in a single coordinated plan of campaign under unified control in charge of the Research Committee of the National Tuberculosis Association. This means a revolution of the major strategy in the conquest of disease, the adoption of the policy of siege tactics and trench warfare on a large scale instead of relying upon accidental advances and the casual attacks of individual investigators as in former times. Progress under the new plan may be slow but is sure, for each foot of ground gained in advances into unknown territory is securely held. A small army of experts has volunteered service in this field, chemists, bacteriologists, druggists, physiologists and physicians, more than a hundred of them, working in various parts of the country on the common problem.

The first objective of the new campaign is the discovery of the cause of the disease. After that is attained the way will be opened for the discovery of a cure for the disease. It has long been known that tuberculosis is due to certain plant-like parasites, bacilli, or in plain English "little rods," which find a lodgment in the cells in the lungs or other parts of the body and there form nests or colonies, in the shape of little nodules, the characteristic "tubercles." But we have got to know more about these bacilli before we can fight them effectively. How does it happen that these little creatures have the power to pull down a strong young man? Why is it that a little local colony of these microscopic invaders can set up fevers and sweats in the entire frame and cause him to weaken and waste away? Do they poison him or what? Do the dead germs or the live ones do the damage? What are they made of? What do they give off while living? What do they leave when dead?

Obviously the first step in the investigation was to set the chemists to analyzing the T.B. bugs. But the chemists demanded that they be supplied with the material to be analyzed by the pound, even by the hundred pounds in the long run. So two of the leading manufacturers of medicines undertook to cultivate the creatures that they proposed to destroy. Fortunately it was found that the tuberculosis bacillus, unlike many microbes, could be made to grow outside of animals and without any animal matter. They would thrive in glass flasks filled with nutrients of known composition, made up of pure chemicals. Consequently any new substances discovered in the dead and dried germs, or in the solutions where they had lived, must be such as have been formed by the creatures themselves and such as they release inside the body. In this mass of crude material then we may expect to find the products that exert the deleterious effect upon the human system.

Although the chemical work may be said barely to have begun, yet it has already resulted in startling discoveries. Two, in especial, are altogether unexpected and without precedent. There have been found, among the toxic constituents of the T.B. germs, two that belong to two of our most familiar food families; an unknown fat that may form tubercles and an unknown sugar that may be fatal under certain circumstances. All the fats and sugars known hitherto are nutritious and innocuous. Not a disreputable member among the scores of fats and sugars found in nature or the hundreds that can be formed by the chemist.

But the newly found fat when injected into an animal will form the

same sort of tubercles as are produced by the living germs. This fat is, of course, devoid of life; in fact has been freed from all other substances in the complicated chemical process of purification. Probably when its structure has been worked out it will be found possible to make it artificially from mineral matter in the laboratory. It contains the same elements as the common fats and it seems similar in constitution to the ordinary fatty acids of foods, such for instance as stearic acid. Yet it is capable of producing all by itself the same little nodules that are characteristic of the disease and have hitherto been found only in the colonies of the living bacilli. The first effect of the injection of this fatty fraction is to stimulate the growth of the particular kind of blood cells that the T.B. bug lives in, and the abnormal multiplication of these cells upsets the balance of the body cells.

The other discovery is still more unexpected. This is a strange sugar which, when injected into the blood of a tuberculous animal, will kill it quickly. Yet it is harmless to an uninfected animal. Somehow the sugar knows. It can make a diagnosis like a doctor—or better than some. Yet the sugar is a white, harmless-looking powder, sort of sweetish like the others, made of the same elements, so it is peculiar that it should prove to have poisonous properties. It seems to act directly on the adrenal glands, causing sweats and fevers, for the secretion of the adrenals controls the temperature reactions of the body. We may surmise in advance of evidence that the familiar symptoms of the disease and its final fatal effects may be due, in part at least, to the constant leaking into the blood of this pernicious product from the T.B. germs as they die and decompose inside the cells of the afflicted individual and so slowly poison him.

This is not the only case of sugar found in disease germs, for recently some unknown sugars have been extracted from pneumonia material.

The healthy person can for a time withstand the pernicious influences emanating from the infected area, but as these increase and his resistance weakens, he fails to react as at first and the rising and falling of his temperature becomes more extreme. We may hope that eventually the chemists will find something that will break down the waste poison of the tubercle bacilli into glucose or other harmless substances.

It is already obvious that the new tactics for the investigation of disease, while at first focussed upon the tuberculosis problem, will throw light upon other diseases and in fact upon the fundamental processes of human physiology. For the three grand classes of components found in these laboratory-raised bacteria, that is, fats, sugars and proteins, are the same as constitute our bodies and our food. But how these three kinds of compounds combine in the body is still a mystery. The chemist has isolated and determined the composition and construction of all the common fats, sugars and proteins. Some of them he even can make synthetically in his laboratory. He can figure out closely just how much of these various ingredients of food are needed for a particular day's work. He can tell, for instance, just how many more foot-pounds a man can lift by adding an ounce of glucose to his ration. The chemist can trace the molecule of glucose through the blood-stream till it gets to the muscle where it is needed. But there he loses track of it. He is still much in the dark as to how the protein in the muscle fiber seizes on to the sugar and gets energy out of it and what part is played by the phosphorized fatty acids present. If he could find out how these three substances are hitched up in normal life, he would most likely be able to find out how they get hitched up wrongly in disease and finally how to correct the blunder.

Edwin E. Slosson
Director of Science Service

THE SCIENTIFIC MONTHLY

AUGUST, 1929

THE FIRST YEAR OF THE *CARNEGIE'S* SEVENTH CRUISE

By W. J. PETERS[1]

CARNEGIE INSTITUTION OF WASHINGTON

JUST about one year ago the *Carnegie* left her prolonged berth in the Washington Channel with eight young scientists on board having ambitious visions of carrying out an elaborate program of observations under the leadership of Captain J. P. Ault. This article is based upon the numerous reports prepared by these young men at sea and compiled in the office. In reading these reports one is impressed with the glowing interest they contain, details of repeated trials with new apparatus, failures that will be overcome, successes already achieved—between the lines, hardships and possibly compensating amenities, for all of which there will be no room in this prosaic account of the work done during the first year of the three-year cruise of the vessel—her seventh—begun May 1, 1928.

MAGNETIC WORK

The six preceding cruises of the *Carnegie* together with three of the *Galilee*, beginning in 1905 under the auspices of the department of terrestrial magnetism of the Carnegie Institution of Washington, had practically completed by 1921 a general magnetic survey of all the oceans, supplying values of the magnetic declination or variation of the compass, inclination and strength of the magnetic field over immense regions in which the navigator had hitherto been forced to rely on magnetic charts constructed on data altogether too meager. This comprehensive survey of the oceans together with contemporary magnetic surveys on land now furnishes material from which a fairly reliable theory of the magnetism of the earth as a whole may be deduced. Even so, changes occur, as the years go by, and charts, diagrams or investigations are made for one selected epoch in order to represent consistent values. Evaluations of the rates of these secular changes are not only required to reduce observed values to a common epoch or from one epoch to another, but they are in ever-increasing demand by investigators correlating the earth's magnetic field with other geophysical phenomena.

The present magnetic program[2] of the *Carnegie* has been planned accordingly to yield primarily, secular variation, and to obtain it with the least effort compatible with trustworthy results. This is accomplished—in part, by improvements in instruments, such as the installation of a constant-speed apparatus to drive the coil of the marine earth-inductor, an amplifier and a micro-ammeter to determine magnetic inclination—in part, by eliminating duplicate observations with two instruments—in

[1] Commander of the survey-ships *Galilee*, 1906–08, and *Carnegie*, 1909–14.

[2] See J. P. Ault, "The Purposes and Program of Ocean-Surveys," SCIENTIFIC MONTHLY, 26: 160–177, 1928.

CARNEGIE UNDER SAIL

SOUTH PACIFIC OCEAN (LATITUDE 2° SOUTH, LONGITUDE 95° WEST).

part, by omitting observations every other day, or here and there as found desirable—and in part, by following the tracks of earlier cruises as closely as circumstances permit with the object in view of making every observation available for secular-variation data.

The passages already made by May 1, 1929, to a point beyond Apia are shown in the chart by the continuous line. The proposed passages of the rest of the cruise are shown by dotted lines. During the first year the vessel was actually at sea 242 days and had sailed 27,800 nautical miles (about 32,000 statute miles). She crossed the Atlantic, recrossed it, entered the Pacific by way of the Panama Canal, and after a loop in the southeastern Pacific to Easter Island, Callao and Samoa, had sailed from Apia on April 20, 1929, for Guam and Yokohama.

Atmospheric Electricity

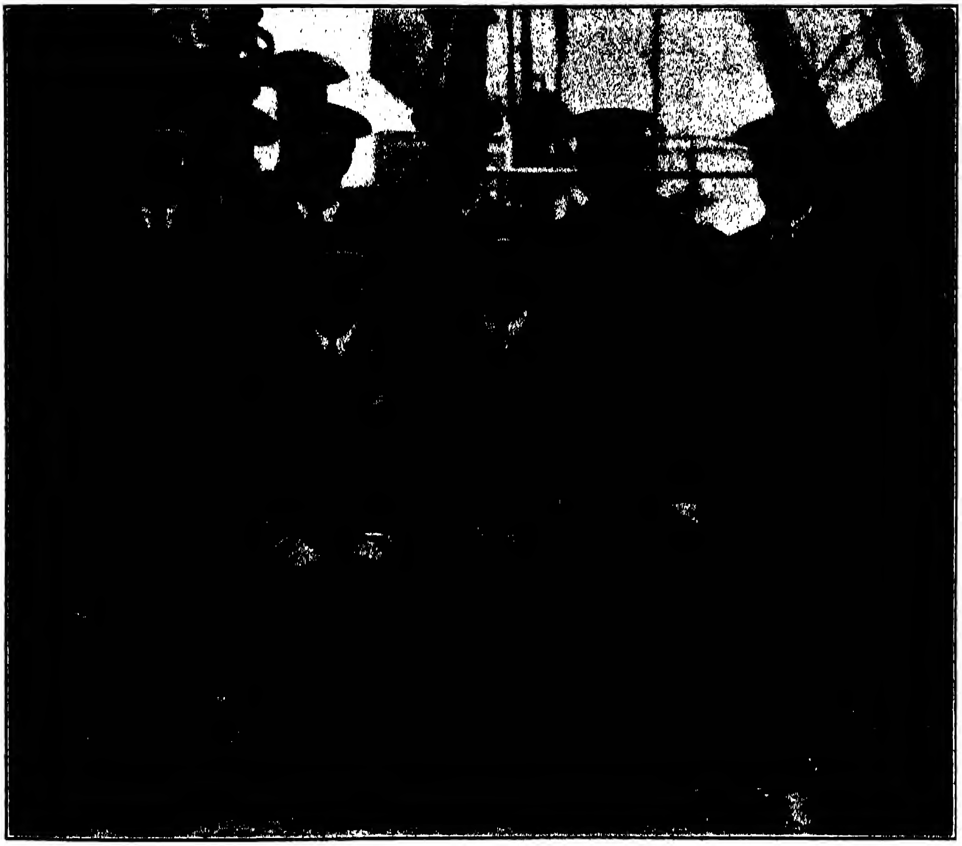
Atmospheric-electric observations were not instituted with magnetic observations on the first cruise of the *Galilee*. Instruments and methods for use at sea were then far from perfect, and although observations were attempted on the third cruise (1907–1908) of that vessel and were continued on the subsequent cruises of the *Carnegie*, the more satisfactory instruments, largely of department design, not being available before the *Carnegie's* fourth cruise beginning in 1915. The end of the sixth cruise, therefore, left much to be desired especially in twenty-four-hour series and in the distribution of observations over the globe. Now by means of photographic methods continuous records of potential gradient can be made as long or as often as required. The apparatus is in a metal box bolted to the taffrail with a collector projecting outboard. The box is really a small darkroom with the recording parts inside. Another instrument for the photographic registration of conductivity will be installed in July after the *Carnegie* arrives at San Francisco to supplement the present eye-reading apparatus. Improvements have been made in the instruments for measuring penetrating radiation, radioactive content and conductivity, thereby offering through greater facility in operation many more opportunities for twenty-four-hour series.

MAIN AND QUARTER-DECK, *CARNEGIE*
As seen from royal yard.

Weather conditions were generally bad on the first passage, Hampton Roads to Plymouth, and some time was required for adjusting new instruments to service conditions and for devising a program that would fit in with other operations.

ROUTE CRUISE VII OF THE *CARNEGIE*, 1928 TO 1931,

FOR MAGNETIC, ATMOSPHERIC-ELECTRIC AND OCEANOGRAPHIC INVESTIGATIONS—CONTINUOUS LINES SHOW PORTION COMPLETED MAY 20, 1929; BROKEN LINES SHOW PORTION PLANNED 1929–1931.



SCIENTIFIC STAFF OF THE *CARNEGIE*
(*Left to right:* SITTING, PARKINSON, AULT, PAUL; STANDING, SOULE, JONES, SCOTT, SEIWELL, TORRESON.)

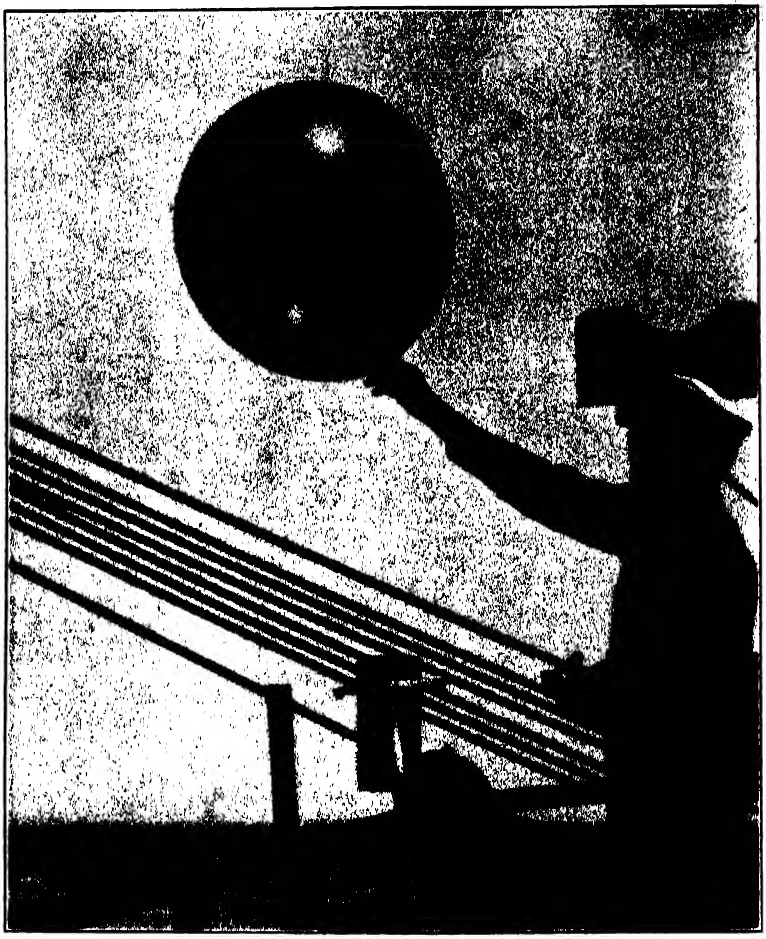
Low values of ionic content and conductivity were found and have been ascribed to stormy weather. At Hamburg, Dr. Kolhörster's penetrating-radiation instrument was received and is being used in observations parallel with the *Carnegie's* instrument.

Between Iceland and Barbados and subsequently observations have been made almost every day. Low values of ionic content and conductivity were obtained as far south as latitude 13° north, after which they were high for a few days before returning to normal on the westerly run to Barbados.

The Aitken dust-counter was used almost daily for nucleation-counts to correlate with atmospheric-electric elements.

METEOROLOGY

The meteorological program has been expanded to include continuous records with the Hartmann and Braun electrical recorder installed in the control-house with three pairs of distant resistance-thermometers, wet- and dry-bulb, the lowest in the shelter house on the quarter-deck, another at the main crosstrees and the highest just below the main truck. These thermograms, which are controlled by the Negretti and Zambra recording psychrometer on the Assman aspiration principle, will furnish data for temperature and humidity lapse-



RELEASING PILOT BALLOON ON BOARD *CARNEGIE*
SOUTH PACIFIC OCEAN

rates from practically the sea-surface to an elevation of about thirty-five meters.

Thermograms are also made for water-temperatures. The thermal element is attached outside to the hull about seven feet below load-water-line and the thermograph is installed in the new oceanographic laboratory.

Fine weather after leaving the canal gave the first opportunity to initiate pilot-balloon flights and to use the new gimbal-mounted theodolite received at Balboa from the navy. Flights were observed thereafter nearly every day during favorable weather, and on several occasions the balloon was kept in view for more than an hour, though the average time was from twenty to thirty minutes. The directions and velocities have been deduced from sea-level to heights of four to twelve kilometers in a region where few, if indeed any, pilot-balloons had ever been released. The new Plath drum-sextant received at Callao was found to be almost a necessity in team-work with the theodolite. The balloon was often picked up first with the sextant, the sextant-measured altitude then set off on the theodolite thereby expediting the pointing of the

theodolite after which simultaneous sights were taken, one for altitude, one for bearing, and the procedure was then repeated again and again.

The evaporation of sea-water is noted on days favorable for the experiment every four hours.

The foregoing are in addition to the customary meteorological observations which have always included hourly reports of wind-direction and wind-velocity, also state of weather and sea by the watch-officers; reports of wet- and dry-bulb thermometer readings and aneroid readings by the watch-officers at the change of watch; continuous thermograms in the shelter-house and barograms in the cabin; special meteorological observations in connection with any diurnal-variation series of some other investigation, usually by one of the scientific personnel, and the regular observations at mean noon Greenwich recorded on the Weather Bureau forms.

Oceanography

The work of deep-sea soundings includes several operations of sounding, subsequent electrical and chemical determinations and the calculations.

The sonic depth-finder was used in 331 soundings in the North Atlantic and again in the Pacific until the oscillator which is installed in the keel failed to function early in November. Then, as the microphones were still in good order an improvised gun made of brass tubing twenty feet long was used to explode shot-gun shells about a foot or so under water on starboard side, that is, on the side opposite to the microphones. The time-interval between explosion and echo was determined by a stop-watch. Sometimes the second echo was heard. A number of these soundings were compared with soundings by pressure-thermometer and with wire-soundings read on the meter-wheel corrected for the angle of drift. The oscillator was overhauled in dry-dock at Callao and has been functioning ever since.

About one hundred miles off the coast of Ecuador in latitude 1° 32′ south, longitude 82° 16′ west, a submarine ridge was discovered on November 8, 1928. This ridge is named "Carnegie Ridge." It rises about 1,800 meters above the general level of the ocean-floor which, here, is in soundings of 3,000 to 5,000 meters. A bottom-sample showed small fragments of lava and obsidian with globigerina-ooze. Another submarine ridge was discovered on January 8, 1929, extending twenty kilometers as the *Carnegie's* track crosses it and rising some 3,000 meters above the ocean-floor, which is more than 4,000 meters below the surface of the sea. In latitude 25° 03.2′ south, longitude 82° 20.0′ west, the crest of the ridge sounded in 1,445 meters and maintained this average level to 24° 54.0′ south and 82° 13.0′ west where it rose to a sounding of 1,260 meters before the final drop began. A bottom-sample showed grayish white globigerina-ooze. This ridge is named "Merriam Ridge" in compliment to the president, Dr. John C. Merriam, of the Carnegie Institution of Washington. It is assumed to be an extension of the uplift forming the islands of San Felix and San Ambrosio.

A deep was discovered on February 16, 1929, in latitude about 15° south, longitude 98° west, which was named "Bauer Deep" after the director, Dr. Louis A. Bauer, of the department of terrestrial magnetism. In a distance of fifty miles the observed depths varied from 2,700 meters to 5,400 meters and back to 4,100 meters.

A ridge rising 2,000 meters above the average bottom was discovered in the Tuamotu Archipelago.

Throughout the passage from Callao to Tahiti the bottom is very irregular, multiple echoes having been received indicating sometimes as many as six surfaces.

The technique of securing bottom-samples had been brought to a high state of efficiency on the Atlantic cruise, and as a consequence bottom-samples were obtained more frequently in the Pacific. The most successful device was the Vaughan snapper with thirty meters of four-millimeter aluminum-bronze wire for drift between the piano wire and the snapper, to prevent kinks in the piano wire after touching bottom. One of the *Meteor* tubes brought up on one occasion twenty-four inches of bottom material, but on a subsequent cast it stuck and was lost, the sounding wire breaking in the attempt to haul in.

All equipment for oceanographic stations is operating well. The Nansen water-bottles, stowed conveniently in racks built for the purpose on the quarter-deck, are quite successful, and the Richter and Wiese deep-sea reversing thermometers rarely fail to record properly. The salinity-apparatus after the design of Dr. F. Wenner, of the Bureau of Standards, for determining salinities by the electric conductivity is very satisfactory. When an oceanographic station has been made in the forenoon the values of salinity will have been determined by evening. That the accuracy of the results is high is indicated by occasional comparisons with results by titration. The reels of the bronze winch on the quarter-deck may be run singly or together, so that on oceanographic stations another wire may be payed out while one is being hauled in. Two series of water-bottles, ten on each line, can, therefore, be collecting at the same time, or a heavier line may be bent to the vertical tow-nets while a series of water-samples and temperatures are being obtained with the other reel.

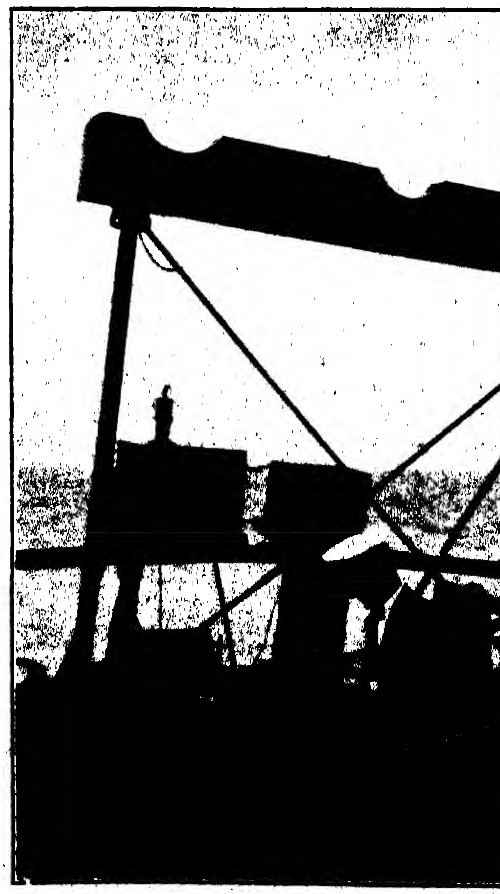
Three bronze davits have been installed, one at the taffrail and one on either side just abaft the main rigging, with bronze fairleads for the bronze sounding wire. Water-bottles and thermometers are attached as the sounding wire leaves the fairleads by observers standing on outboard platforms. Two thermometers are used with each water-bottle, one unprotected and calibrated for pressure gives a check on the depth at which the temperature and water-sample are secured. Water-samples and water-temperatures are usually secured at each ocean-station practically every other day at the following depths in meters, 0, 5, 25, 50, 75, 100, 200, 300, 400, 500, 700, 1,000, 1,500, 2,000, 2,500, etc., to a lowest of 5,500 meters in two series using eight to ten bottles on each wire for each series.

PETTERSSON PLANKTON-PUMP READY TO GO DOWN

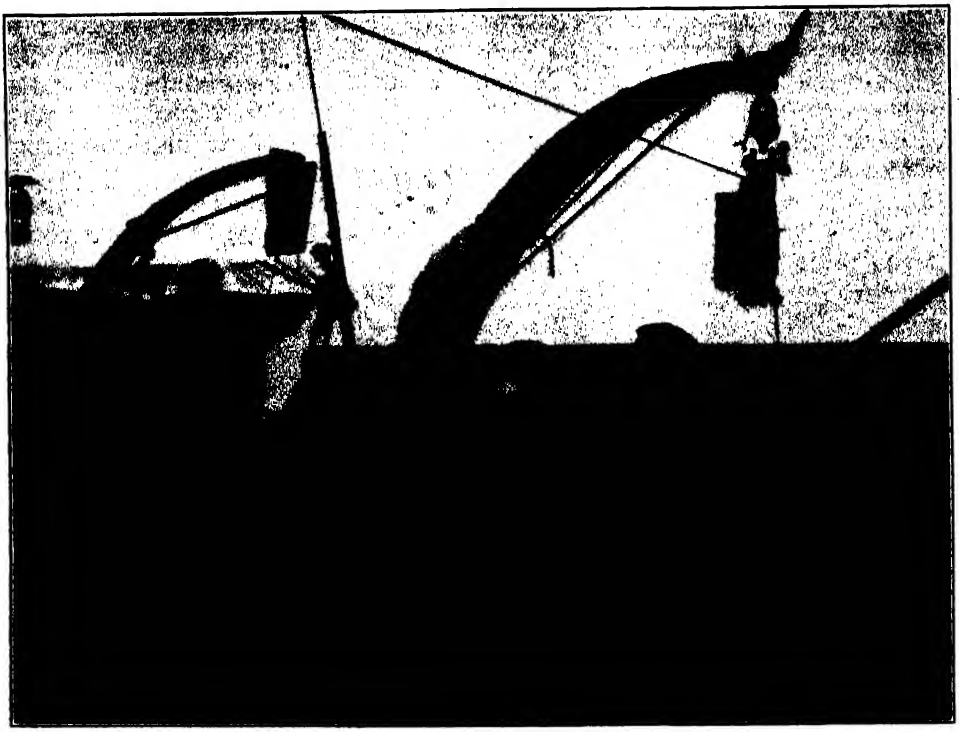
The calculations of density, dynamic depth, pressure, specific volume and their anomalies for the various depths are made on board in accordance with the method of V. Bjerkness (1910) as modified by Hesselberg and Sverdrup (1915). These are the data required for calculating the velocities of any layer of water from the surface down to the average depth reached. The number of solenoids down to a depth of 2,000 meters where the velocities are assumed to be zero is computed, a solenoid being formed by the intersection of surfaces of equal pressure (isobaric) with surfaces of equal specific volume (isosteric). The number of solenoids is a measure of the force tending to cause circulation. Preliminary reports on the results for the cruise in the North Atlantic and for passages in the southeastern portion of the Pacific Ocean (Balboa to Callao and Callao to Papeete) prepared by Captain Ault are being finally checked for publication. Two tables showing the observed and computed values of the various elements involved and graphs giving the details for temperature, salinity, density and specific volume are to be included in these preliminary publications. These graphs bring out many interesting facts, the details of which will appear in later communications. Preliminary publications are to be made in order that the data may be available for the use of students and investigators of oceanography at the earliest moment. This procedure is in accordance with our usual practice of publishing preliminary results in terrestrial magnetism. Even now the magnetic results obtained as far as Apia are either published or are in press.

The number of oceanographic stations between Washington and Plymouth was limited to six by heavy weather, adjustments of new equipment and the training of personnel. Two stations were made between Hamburg and Iceland and four more before reaching the Grand Banks of Newfoundland. During the stretch southward eleven stations were made before the westerly run to Barbados on which six more were made. At all stations but one, depths from 2,000 to 5,500 meters were reached.

The results in the North Atlantic confirm the conclusions presented by Helland-Hansen and Nansen in their book, "The Eastern North Atlantic," as regards the relation between observed values of temperature and salinity. The variations from a general curve are mostly accounted for by the presence of water of low salinity as compared with



APPARATUS ON TAFFRAIL OF *CARNEGIE*
FOR PHOTOGRAPHICALLY RECORDING THE POTENTIAL GRADIENT OF THE ATMOSPHERE.



REMOVING NANSEN WATER-BOTTLE AT OCEANOGRAPHIC STATION

temperature. For example, the presence of polar water is indicated at stations in the Greenland and Labrador streams. The results serve to emphasize the desirability of repeat-observations in the same localities for shallower depths in order to secure anything like an adequate view of the system of surface and near-surface circulation.

The records obtained between Balboa, Easter Island and Callao were made at five oceanographic stations in and near the Gulf of Panama, six stations along the westward stretch to about 105° west longitude past the Galapagos Islands, eight stations thence to Easter Island, six stations on the southeasterly run from Easter Island to latitude 40.5° south before heading up on the northeasterly stretch to Callao during which eleven stations were made. Captain Ault's preliminary reports state:

> The charts, giving the results by these sections, present the physical conditions of the ocean water down to 2,000 meters in a very striking manner. The low-salinity fresh water near the coast is shown. Then we enter the high-salinity warm water, coming down from the central Pacific, before crossing into the cold, up-welling, turbulent waters of the sub-Antarctic as we approach the latitude of 40° S. The crossing of the Peruvian or Humboldt Stream is marked in the north off the coast of Ecuador, and again in the south as we approach the coast of southern Peru. Data from the next portion of the cruise will add materially to the picture of the physical conditions of the ocean waters of the South Pacific Ocean.

Marine Biology

The work in marine biology, confined mostly to microbiology to determine the abundance and distribution of plankton and other small organisms, has been carried on vigorously. The methods and apparatus are in large measure new; on the whole they have been satisfactory. The large plankton half-meter and meter tow-nets after the "Michael Sars" design with improvements and made of Dufour silk bolting-cloth are

described by H. R. Seiwell,[3] chemist and biologist of the expedition, in the *Journal of the International Council for the Exploration of the Sea.*

The tow-nets are used at each oceanographic station at the surface, also at 60 and 120 meters below. The Pettersson plankton-pump is also used at the same depths. The nets have been generally satisfactory, except during excessive rolling when it is difficult to avoid tearing them. Experiments are being made with aeroplane shock-absorbing cord for the bridles. The last advices state that aeroplane rubber-rope bent to the inboard end of the towing line is being used with success.

Trouble with the Pettersson plankton-pump was also experienced when the vessel, hove to, was rolling heavily, but a number of adjustments and improvements made at sea now render this instrument serviceable under almost any condition likely to be encountered. The quantitative plankton-pumpings obtained with this instrument are considered to be the best ever made on the high seas, and they will show, when worked up, the relation between the zooplankton and the phytoplankton to 100-meter depths. A large amount of biological collecting is done with tow-nets and dip-nets dragged from a special boom-walk similar to the one used by Beebe, which is lowered by a pendant from the starboard fore-rigging. This boom-walk enables the collection to be made well out from the wash of the vessel.

In addition to the biological work concerned chiefly with the plankton, occa-

[3] See *J. Conseil Internat. pour l'Exploration de la Mer,* 4: 99–103, 1929.

USING DIP-NET FROM THE BOOM-WALK OF *CARNEGIE*

sional tows and dredgings are made in shallow water for diatoms and *Foraminifera*. The chemical studies in inorganic phosphate, nitrate and hydrogen-ion concentration are intimately tied up with the phytoplankton.

The advantages of receiving radio time-signals and the almost daily communication with the office can hardly be overstated. The uncertainties in the rates of five or six chronometers carried on the earlier cruises made it necessary to postpone final corrections to the longitudes of sea stations until time-signals could be obtained at the next port. Now final longitudes are obtained on the day following the stations for which they are required, with a vast reduction in the work of comparisons and computations.

All preliminary computations are made and checked on board and are promptly mailed to the office with all records at each port.

During the first year of the present cruise there have been made 350 magnetic declination-observations, 110 inclination and horizontal-intensity observations, 98 oceanographic stations, 800 sonic-depth determinations, 225 atmospheric-electric observations, 90 balloon-flights and 50 collections of bottom-samples, besides the daily and continuous records of air and water-temperatures, of humidity and of pressure.

The scientific staff of eight are: Captain J. P. Ault, commander and chief of scientific staff; Wilfred C. Parkinson, senior scientific officer; Oscar W. Torreson, navigator and executive officer; F. M. Soule, observer and electrical expert; H. R. Seiwell, chemist and biologist; J. H. Paul, surgeon and observer; W. E. Scott, observer; Lawrence A. Jones, radio operator and observer. Dr. H. U. Sverdrup, of the Geophysical Institute, Bergen, Norway, research-associate of the Carnegie Institution of Washington, is consulting oceanographer.

The preparations for the current cruise had and have generous cooperation, expert advice and loans or donations of much special equipment and many reference books on board, from government and private organizations and individuals interested in oceanographic research both in America and Europe. For these the Carnegie Institution of Washington is indebted to many organizations at home and abroad.[4]

From considerations of the data already obtained and above briefly noted, it is believed that Cruise VII of the *Carnegie* will yield much valuable material to enrich many branches of geophysical research. It is hoped that the development of technique, the improvements of apparatus and methods and the results obtained during the cruise may be helpful in stimulating and may serve as a general basis for future intensive surveys in the vast oceanic areas.

[4] For a detailed list of these organizations and individuals see J. A. Fleming and J. P. Ault, *Zs. Ges. Erdk.*, Ergänzungsheft 3: 55, 1928.

WAVE MECHANICS

By Professor C. F. HAGENOW
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PROBABLY no modern theory of the atom, since Bohr, has attracted more attention or been more often mentioned than the Schrödinger theory. This is to be explained, of course, mainly by the fact that it is the only one which, even in a limited degree, lends itself to a representation by physical models. This theory, however, from its very nature, is a logical part of a more general topic that goes by the name of wave mechanics. The object of this article is avowedly to deal with this topic only in a very broad and general manner.

Dr. Karl K. Darrow,[1] after referring to those physicists who "yearn for continuity in their images of nature," remarks that the theory of wave mechanics "has captivated the world of physics in a few brief months because it seems to promise a fulfilment of that long-baffled and insuppressible desire." The old saying regarding the pendulum swinging to the other extreme is remarkably exemplified in the general aspects of this new theory of the atom. For, while the older quantum theory sought to replace our time-honored wave-motion by corpuscles of energy, this theory requires just the reverse, since now the ultimate particles of matter are themselves regarded as systems of waves of a certain sort.

This is really an extraordinary reversal of view-point, for the whole trend of physical science has been in the direction of atomicity. Among the earliest Greek philosophers we have our atomists, such as the famous Democritus, though the atomic theory of matter can scarcely be called a scientific theory until Dalton provided it with an experimental substratum many centuries later.

[1] "Introduction to Wave Mechanics," *Bell System Technical Journal,* 6: 653. 1927.

It seems but yesterday that we spoke of an "electric fluid," or of two of these fluids. Now this mysterious fluid has gone the way of all matter and has become granular, with the exceedingly fine grains, *i.e.,* electrons, that Millikan has measured so accurately. Students often call them "discreet" (discrete) particles, but it seems to-day as if these particles have not always been "discreet" enough, for a number of our experimental physicists have recently detected them in a most unparticle-like behavior, a subject to which we shall revert later.

Next we were asked to consider the possibility of light being propagated as corpuscles. The fact that a corpuscular theory of light had been the prevailing theory for a century after Newton made matters all the worse, for it seemed too much like a ghost-walking business. This particular ghost, *viz.,* the corpuscular theory of light, was one that was thought to have been laid for all time. Experiment after experiment, in all branches of optics, fitted in so perfectly with the wave theory of light that Hertz could say in 1889, "The wave theory of light is, humanly speaking, a certainty."

Unlike their predecessors, the light corpuscles, these waves required a medium in which to travel, and a "luminiferous ether" was provided. There is a certain naïveté in the very choice of this adjective which was not lost on a certain prominent president of the British Association for the Advancement of Science a generation ago, who remarked that the chief function of the ether was to furnish the subject for the verb "to undulate." Yet it is characteristic of the philosophic attitude of that time that it could seriously be said, "There is as much reason for believing

in the existence of the ether as in that of shoemaker's wax."

One of the chief trouble makers of the supposedly firmly established wave theory is the *photoelectric effect*. Photoelectricity was genially defined recently by a physics student as "the production of a photo by means of electricity through light rays." The discerning reader will doubtless perceive that we have to do with a phenomenon widely applied in the transmission of photographs and television. The basic phenomenon is simply that of the liberation of electrons from certain metallic surfaces when the latter are struck by light of appropriate wave-length. This has often been described, and is mentioned here only to call attention to the fact that a corpuscular theory of light is imperatively demanded by certain experiments connected with this emission of electrons by metals when illuminated with the proper wave-lengths. Thus the energy with which the electrons are emitted is entirely independent of the intensity of the incident light, but depends only on the frequency vibration of that light. A spreading, and therefore constantly attenuating, wave will simply not provide energy enough. What is required is particles that conserve their energy *regardless of the distance they have traversed before striking the emitting surface*. As Sir William Bragg has so vividly illustrated this point:

> It is as if one dropped a plank into the sea from a height of 100 feet and found that the spreading ripple was able, after traveling 1,000 miles and becoming infinitesimal in comparison with its original amount, to act upon a wooden ship in such a way that a plank of that ship flew out of its place to a height of 100 feet.

Now this new hypothesis contains another yet more startling implication. For if light, or more generally, radiation, is propagated as corpuscles, so is the energy that this radiation represents. The amount of energy in each of these little "parcels" is expressed by the product of two factors, namely, the frequency of vibration of the radiation and the world-famous universal constant known as Planck's h. Algebraically expressed it is $h\nu$, the "quantum" of energy. Of course, the magnitude of the quantum may vary. Thus a quantum of radio radiation is much smaller than a quantum of visible light, and an X-ray quantum is larger still.

We have thus arrived at the end of an "atomizing" process. Matter, electricity, light, energy—all seem to be made up of exceedingly small, but finite, particles. What is left? The ether? With light and energy shot out as corpuscles, what need have we of an ether? Under these conditions one may well ask, with respect to the new wave theory of matter, where and how did such a revolutionary, or rather counter-revolutionary, theory arise? New as it is, however, it can boast of a very aristocratic ancestry of ideas and principles.

Here, again, we are delving into the past and are about to work over old material. Without going into mathematical details, it must suffice to state that nearly a century ago Hamilton developed certain relations between the motion of a particle and a wave-motion, relations that have been elaborated and extended by Louis de Broglie and Schrödinger in a truly remarkable, not to say startling, manner. Guided by a certain striking resemblance between two famous theorems dating back to Huygens and Maupertuis, de Broglie proposed a bold hypothesis to the effect that there is associated with every particle of matter a wave-motion such that the relation between the motion of the particle and that of the accompanying wave can be expressed by the equation

$$uv = c^2,$$

where u is the velocity of the wave, v the particle velocity and c the velocity of light *in vacuo*. Relativity also enters

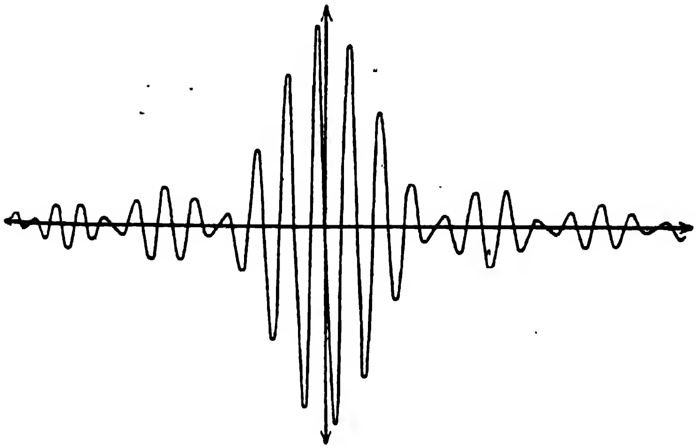

FIG. 1. FROM "DIE NEUE MECHANIK," BY LUDWIG FLAMM, *Naturwissenschaften*, 15: 569. 1927.

in, but the details must be omitted here.

But a serious obstacle seems to present itself at this stage. For, since in the relativity theory no material particle can have a velocity greater than that of light, it is easy to see from the above equation that if v is less than c, u must be greater than c. Thus the hypothetical wave associated with the particle would travel faster than light itself.[2] However, the difficulty vanishes when the "group velocity" of these waves is taken into consideration. What is meant by group velocity can best be explained by referring to a phenomenon that can actually be observed on a water surface. Drop a stone into still water; the resulting wave soon becomes a group of waves of different wave-lengths and velocities. The crest of this group moves out with a certain velocity while the individual waves pass through it (in this case with greater velocities) from rear to front. More abstractly, whenever a number of waves of various wave-lengths are traveling through a medium in which the velocity of propagation varies with the wave-length, then that part of the combination in which the various waves are most nearly in phase (in step) with each other, *i.e.*, the maximum amplitude, will itself move along with a velocity different from that of any of the constituent waves. It may be well to point out that this group velocity is also the velocity with which the energy of any wave propagation is transported. Figure 1 represents such a group, the crest shown by the arrowed line. A very short distance on each side of this peak interference rapidly decreases the amplitude of the group.

Another illustration of this phenomenon familiar to physicists is furnished by the behavior of light in carbon disulphide. Michelson, by actual measurement, found the ratio of the velocity of light in air to that in carbon disulphide equal to 1.77. On the other hand, the index of refraction of carbon disulphide is only 1.64, which is to say that the velocity of light in air should be 1.64 times as large in air as in the liquid. This discrepancy of 7.5 per cent. is entirely accounted for by the fact that the group velocity of light in carbon disulphide (which is what is measured by the revolving mirror method) is 7.5 per cent. less than the wave velocity, which is the one that determines the index of refraction.

To return to the waves associated with the moving particle, calculation shows

[2] Not the first instance of the appearance of a "super-light velocity" of wave propagation in theoretical physics; *e.g.*, light propagation in some metals is attended by such velocities.

that the *group velocity* of the "super-light velocity" waves comes out exactly equal to the *particle velocity*. We have, then, this situation: *A moving material particle can be thought of as being connected with a vibration whose wave velocity exceeds that of light, but whose group velocity (the energy carrier) coincides with the actual velocity of the particle.* Referring again to Figure 1, we can now look upon this group of waves as a sort of model of what is called a "wave-corpuscle."

We come now to a very important feature of the theory, namely, the consideration of the energy of this wave-corpuscle. Since it partakes of the nature of both a material particle and a wave system, we can express its energy according to these two aspects. Naturally these two expressions of the energy must be equal to each other, and this equality constitutes de Broglie's basic assumption. Let us take first the energy of the particle considered as a vibration. This energy is expressed by the product $h\nu$, where ν is the frequency of the vibration and h is the Planck constant. The reader is doubtless not entirely unprepared to meet again with this h in the expression for an energy of vibration. One simply can not get along without it. Like the "Leitmotif" in a Wagner opera, it bobs up again and again, reminding us that in some mysterious way it plays a central rôle in every physical phenomenon.

Next consider the energy of the particle as a bit of matter. This is not the energy due to its motion or position (*i. e.*, kinetic or potential energy) but its *intrinsic* energy considered simply as mass, that is to say, a certain quantity of matter. The amount of this intrinsic energy, according to Einstein, is expressed by the product of the mass and square of the velocity of light *in vacuo*. Thus if one gram of matter could all be converted into energy it would yield 9×10^{20} ergs of energy. If this process of converting matter into energy could be realized in practice, our fuel problem would be solved once for all. For example, suppose some one in King Tut-ankh-Amen's day had started an engine with just one ounce of "fuel" that could be gradually converted into mechanical energy at a rate to keep the engine running without a stop with an output of thirty horse-power. The engine would be going yet, with some three hundred years to run before this ounce of matter would be entirely consumed.

We can now write de Broglie's fundamental assumption, which is, as remarked above, the statement of equality of the energy of the moving particle as calculated from the two view-points, namely, as a vibration and as a mass. He puts

$$h\nu = mc^2. \qquad (1)$$

Now, using the well-known relation between velocity, frequency and wave-length,

$$u = \nu\lambda,$$

we have

$$\lambda = \frac{hu}{mc^2}$$

and finally, since

$$uv = c^2,$$

$$\lambda = \frac{h}{mv}. \qquad (2)$$

Here is a surprising result. *The wave-length associated with a mass, m, moving with a velocity v, is given by Planck's h divided by the momentum of the particle.* (The reader is now in a position to figure "the wave-length" of his car as it bowls along the highway!)

De Broglie applied his theory to the atomic orbits of the Bohr theory and derived, in a very natural manner, many of the results of the latter theory that were obtained earlier by more or less arbitrary assumptions. The question of the "naturalness" of these derivations is debatable. It may almost be said to be a matter of the reader's temperament or taste. A friend who is especially well

versed in wave mechanics remarked: "It may be true that de Broglie's additional assumptions may be more natural than those of Bohr. As for myself, I am undecided just which of the two is the better conjurer."

But one does not ask for the credentials of a theory; the first question is, can we put it to the test of experiment? If this particle travels along disguised, as it were, as a group of waves, what will happen if it should pass very near some obstacle, or through a narrow opening? The reader may perhaps have observed the behavior of fairly large water waves as they pass by an obstacle, for example, the curves of a pier or breakwater. The wave, as it passes, will be seen to curve into the region *behind* the obstruction. The same phenomenon occurs in the case of light and sound. We are not surprised to hear around a corner, and light waves behave in a similar manner provided the obstacles are small enough in proportion to the very small dimensions of a light wave. When you next look at a distant light through a Pullman screen or through the covering of your umbrella, notice the patchwork of light and shadow that constitutes the "diffraction pattern," which is all the image of the source of light you will be able to see under the circumstances. The actual outline of the light is almost entirely destroyed by the confusion of the multiple images produced by the "diffraction" (bending around) of the light waves. This phenomenon is an essential characteristic of all wave propagation, and a moving particle might be expected, on the above theory, to manifest some sort of diffraction effect when very near obstacles of comparable size.

Such an effect was, indeed, found to be present in the case of moving electrons by Davisson and Germer[3] a short time ago. They showed that electrons impinging on nickel crystals were diffracted very much like X-rays. This looks like a most promising step in the direction of the much-desired harmonization of the outstanding conflict between the wave theory and the corpuscular theory of radiation, truly a "consummation devoutly to be wished." Unfortunately we are still confronted, at this stage at least, by a serious discrepancy existing between the two cases, *i.e.*, between the diffraction of light and the diffraction of electrons. If light *is* corpuscular, then corpuscles, or "photons" as they are called, do not affect one another in their respective paths, as do electrons, since electrons in motion constitute electric currents and these do interact in the well-known manner.

Before taking up the Schrödinger theory let us review very briefly some of the elements of the Bohr theory of the atom, the very one that these later wave-mechanics theories are designed to supplant. It is essential that the reader have a clear notion of some of the features that any theory of the atom must be able to explain. One of the most important of these features is a "physical picture," with its attendant mathematical formulation, that will yield correctly the wave-lengths or frequencies of the spectral lines of the elements.[4] According to the Bohr theory, the frequency of a particular spectral line is given by

$$\nu = \frac{E_1 - E_2}{h},$$

where E_1 and E_2 denote the energy values, respectively, that are associated with two orbits of an electron, such that radiation of frequency ν is emitted when the electron falls from one orbit into the other. For definiteness let us think of the hydrogen atom with its one electron. No emission occurs while the electron

[3] A very interesting account by Dr. C. J. Davisson will be found in the SCIENTIFIC MONTHLY for January, 1929. Also, by the same author: "Are Electrons Waves?" *Jour. Franklin Inst.*, 205: 597. 1928.

[4] It must be confessed, however, that in recent years the physical picture threatens to become obsolete; not so much because the theorist is more inclined to dispense with it, as because such a physical model is often quite impossible.

revolves in any one orbit, and we say, then, that the electron is in one of its *stationary states*. Moreover, Bohr assumed that only certain orbits were possible for the electron, namely, those for which its angular momentum about the nucleus was equal to a *whole number* multiple of $\frac{h}{2\pi}$. Denoting the mass of the electron by m, its velocity by v and the radius of the circular orbit by r, this assumption states that

$$mvr = \frac{nh}{2\pi},$$

where n is always a *whole number*. That is to say, the orbits or stationary states have been "quantized." Of course no one knew (or knows now) *why* these orbits should be so restricted, but the theory "worked" and one is reminded of the saying: "Nothing succeeds like success." However, the point to keep in mind is this matter of "quantization." I might substitute the older term, used earlier in this article, and call it "atomization." Nature seems to work that way,[5] and the theorist racks his brains for a more or less plausible theory to make the process seem "natural." Some great mathematician, I believe, once said something to the effect that nature had no regard for analytical difficulties.

Now the Schrödinger theory proposes to educe this quantization from certain basic mathematical principles, thus dispensing with a special postulate toward the desired end, as in the case of Bohr. As Schrödinger himself states, "The essential thing is that this quantization no longer appears as a mysterious 'Ganzzahligkeitsforderung' (whole number requirement), but is carried a step further back, as it were, finding its basis in the finiteness and uniqueness of a certain space function." This sounds rather abstract and is intentionally so on Schrödinger's part, but certain analogies can be attempted for sake of a clearer comprehension. The new theory is partly based on the same principles de Broglie employed, and in his first paper on the subject Schrödinger gracefully acknowledges his indebtedness to the French physicist.

It is impossible to give a physical picture of the theory as a whole, principally because it is, in essence, mathematical, and much of the mathematics does not lend itself to physical representation by means of models. Like de Broglie, Schrödinger also associates a vibration with the electron but he develops this vibration into a standing wave instead of the moving or advancing wave of his predecessor. An illustration of standing or stationary[6] waves is, fortunately, easily supplied. Consider the vibration of an ordinary violin string, for instance. When plucked or bowed, it assumes the familiar spindle-shaped form shown in Figure 2. Since all points

FIG. 2

of the string move up and down in step (though not through the same distance) this form of wave-motion is described as stationary or standing waves. Again, when the violinist places his finger lightly on the middle of the string, the first overtone or harmonic is sounded, and the string appears as in Figure 3. The frequency is, of course, twice that

FIG. 3

[5] The famous "Natura non facit saltum" seems to have followed the "horror vacui" into desuetude.

[6] This term is here not synonymous with "stationary" as used in "stationary states." The latter use of the word was no doubt suggested by its earlier application to this type of wave-motion. As will be seen further on, these stationary waves *do* correspond to stationary states in the Schrödinger theory.

of Figure 2, *i.e.*, the tone is an octave above the first one. Similarly we can have three segments, or loops, with three times the fundamental frequency, and so on.

Now this picture is of special interest just here as it brings out clearly the fact that, in order to have a well-developed system of such standing waves, it is indispensable that the length of any of the equal segments be an aliquot part of the length of the string, or, in other words, only those frequencies are emitted which are whole number multiples of the fundamental frequency shown in Figure 2. Describing this state of affairs in modern terms, we say that the frequencies of the vibrating string have been "quantized." Each of these modes of vibration, emitting its characteristic frequency, corresponds to the various orbits of the electron in the Bohr model of the hydrogen atom discussed above.

Employing, for the sake of illustration, such a vibrating string as an extremely simple atom model, we should describe the situation as follows: No radiation is emitted while the atom is in one of its stationary states, *i.e.*, in one of its states of a single characteristic vibration. But suppose two such characteristic vibrations to occur simultaneously. In the language of acoustics, a beat frequency would result; a radio fan would call it a heterodyne frequency. Now it is this beat frequency that constitutes the frequency of emission. Since the number of beats per second produced by two tones is equal to their frequency *difference*, it is obvious that this conception of Schrödinger is mathematically equivalent to the Bohr equation for emission. For we had, on page 113,

$$\nu = \frac{E_1 - E_2}{h},$$

or

$$\nu = \frac{E_1}{h} - \frac{E_2}{h},$$

the two terms on the right corresponding to these simultaneous stationary states of vibration. Thus we have in the Schrödinger atom a coexistence of two states of vibration while the atom is radiating, while in the Bohr atom radiation takes place during a transition from one stationary state to another. Schrödinger thinks of this coexistence as taking place while energy is being transferred from the one vibration to the other.

Unfortunately, this simple picture is quite inadequate for the complete representation of a system which is even simpler in structure than a hydrogen atom. When we attempt to picture a hydrogen atom, the situation becomes still more complicated. The "waves" lose all reality. And yet, in the remarkable experiment of Davisson and Germer mentioned above, the waves associated with a moving electron seemed real enough. We have indeed traveled a long way from our "billiard ball" atom of old!

No discussion of the Schrödinger theory would be at all recognized as such without some mention of his famous symbol "ψ" which, in one instance at least (I was told), had "broken" into the editorial page of a metropolitan newspaper. This symbol appears in many guises—I had almost said disguises. In the extremely simple case of the vibrating string, discussed above, it may represent simply the instantaneous displacement of the particles of the string from their position of equilibrium. But the atom is composed of electric constituents, and the so-called vibrations are not to be thought of as mechanical motion, but as electrical fluctuations of some sort. Considering only the hydrogen atom, Schrödinger found good agreement with experiment (*e.g.*, measurements on the relative intensities of spectral lines) by putting the square of the amplitude of ψ equal to the density of the electric charge, in this particular case the charge of the electron. But, mathematically, ψ has a value throughout space, hence the

electron must occupy all space! However, calculation shows that practically the whole charge of an electron is concentrated within a sphere of the order of 10^{-8} centimeters diameter, which is, in fact, the atomic magnitude. Such an agreement can surely not be a mere accident. It is the *fluctuation* of this electrical density which determines the character of the emitted radiation corresponding to the interorbital jumps of the electron in the Bohr atom. On the other hand, a *constant* electrical density is unaccompanied by emission, being therefore a stationary state, just as the revolution of the electron in any one orbit constitutes a stationary state in the Bohr atom.[7]

But this simple picture must again be abandoned when more complicated systems are considered and ψ becomes more and more a mathematical abstraction. There seems to be a tendency away from "physical pictures." Our imaginary atomic machinery is necessarily suggested by our experience with large-scale objects and their relation, and it would be strange indeed, it seems to me, if such structures were found to be workable in all respects in an alien atomic world. The argument has even been advanced, notably by Heisenberg, that we should definitely renounce all attempts at such picturization, *e.g.*, the position and orbital velocities of electrons in the atom, since we can never hope to verify them by experiment. We should work only with those quantities that are directly observable, such as the frequency and intensity of spectral lines. Heisenberg's "quantum mechanics" bears witness to the successful application of this principle. Yet there are still other ultramodern rivals of the Schrödinger theory. One wonders if this period of almost feverish activity has its equal in the whole history of physics.

[7] The reader is cautioned that this varying electrical density is of a purely theoretical character and not susceptible of direct measurement.

STUDIES IN EXPERIMENTAL EMBRYOLOGY BASED ON SEA-URCHIN EGGS[1]

By Dr. D. H. TENNENT

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THE living organism is unlike any mechanical contrivance in that it can reproduce itself. It is self-perpetuating.

The essential reproductive cell is the egg. The egg may be regarded as a detached portion of a living organism, specialized for the purpose of reproducing its kind and bearing the characteristic organization of the species to which the individual producing it belongs. This organization is inherent in the egg and is preserved through each generation. We can say little regarding the precise nature of organization. We know, as Von Baer knew, that the embryo is not preformed in the egg, and we know, as he knew, that it does not come from an undifferentiated mass.

The egg is a cell. Its cytoplasm is maternal in origin; its nucleoplasm, when biparental development is concerned, has come from the father and the mother of the individual producing the egg. In many organisms it is possible to trace the germ cells back to the cleavage stages of the egg. In the sea-urchins the earliest stages of eggs that have been observed are small cells in the wall of the sac-like ovary. These germ cells, potential ova, are ameboid in form. They contain a nucleus and homogeneous protoplasm. It seems probable that the living primordial germ cell is simply a bit of undifferentiated protoplasm, living substance, with its nucleus. At this stage nothing in the nature of formed components, inclusions, may be seen within it. As the growth of the cell proceeds, substances are taken into it from surrounding cells and it increases in size, the increase in size being due in part to the increase in amount of living substance and in part to the formation and inclusion of nutritive materials, deutoplasm, stored for the needs of later development.

One may distinguish between living substance (protoplasm), included materials (deutoplasm) and transitional stages between these two, each being the end product of a reversible reaction.

The included substances are organic compounds formed as a result of interaction between nucleus and cytoplasm. With the microscope one does not see the actual formation of these compounds. They become visible only after the aggregations have become big enough to be seen with the microscope; *i.e.*, when they have reached a size above 100 mμ. If one makes use of the ultra microscope still smaller particles may be seen. Secondary colloidal particles are said to range in size from 5 to 100 mμ. Finer and finer subdivision beyond the limits of any direct observation is conceivable.

Lyon found that by centrifuging sea-urchin eggs it was possible to produce stratification of visibly different substances. The work of Conklin, Morgan and others showed that centrifugalization did not modify the organization of the living substance. Formed components, inclusions, were moved through the living substance without destroying its integrity, without changing its organization.

What do we know of the organization of the egg?

In the sea-urchin egg a micropyle may be demonstrated. This is at the "animal" pole of the egg. It is at this point that the polar bodies are always

[1] A lecture delivered before the Carnegie Institution of Washington, April 16, 1929.

formed. The "vegetal" pole is the opposite pole of the egg. The principal axis of the egg may be regarded as extending through the egg from pole to pole.

The egg has polarity. The anterior end of the larva always coincides with the animal pole of the egg; the micromeres, and in turn the mesenchyme cells, are always formed at the vegetal pole. The egg seems to carry as an inherent quality the polarity of the organism from which it came. Boveri and Driesch referred polarity to the polarization of the ultimate structural particles of which the ooplasm is built.

Polarity is basic. It is the fundamental feature of organization. Historically, with the establishment of polarity the major axis of the embryo is determined. What is the next step? Does it lie in the separation of organ-forming materials or is there some more general and fundamental feature of organization?

It is commonly assumed that the sea-urchin egg is radially symmetrical around the egg axis. Is this a fact? When is bilaterality established? Is it induced from the outside or does it exist in the unfertilized egg? What determines the bilaterality of the parthenogenetic larva?

It is conceivable that symmetry is a fundamental attribute of organized material, secondary only to polarity, and that the establishment of minor axes incident to bilaterality is the first step in the cytoplasmic differentiation of the larva, taking precedence historically over the processes of differentiation of organ-forming materials.

Thus far we have made rather general statements. Their significance will become more apparent when they are specifically applied to material on which investigations have been made.

Boveri found that in the eggs of the sea-urchin *Paracentrotus* scattered pigment became concentrated, during maturation, in a ring-like zone lying in the vegetative half of the egg and standing at right angles to the axis of the egg. He concluded that the three zones made evident in the ripe egg by the pigment ring correspond to the three primitive organs of the larva; the vegetative, unpigmented cap furnishing the primary mesenchyme and therefore the larval skeleton, the pigmented zone containing the material for the digestive tract, and the unpigmented animal half of the egg providing the material for the ectoderm and its differentiations. His results led to the generally accepted inference that a similar zone exists in the eggs of other sea-urchins, although it is not made visible by the localization of pigment, and that this zone separates the animal half, containing potential ectoderm, from a vegetative cap of micromere-forming material.

This segregation of materials in the unfertilized egg and the fact that the materials thus segregated were separated from each other during the first four cleavages of the fertilized egg seemed to constitute a demonstration of epigenetic development prior to fertilization.

Early in the course of an investigation on eggs of the sea-urchin *Lytechinus* at the Tortugas Laboratory, work done in collaboration with Dr. C. V. Taylor and Dr. D. M. Whitaker, a report of which has recently been published by the Carnegie Institution, it was found that in the *Lytechinus* egg there is no completeness of separation of potential germ layers prior to fertilization. The work involved the cutting of the eggs with glass or quartz needles, under the microscope, into two fragments, each of which was subsequently fertilized. The eggs were carefully oriented and the cuts made either in a plane at right angles to the principal axis of the egg, in a plane parallel to it or in a plane intersecting the principal axis obliquely. The eggs were cut accurately, cleanly,

in any desired plane, and into fragments of any desired relative size.

The two fragments, one containing the egg nucleus, one without a nucleus, were then washed, placed in small dishes and fertilized. It is evident, therefore, that after fertilization the nucleated fragment will contain a fused egg and sperm nucleus, and that the non-nucleated fragment will contain only the sperm nucleus. Both fragments are capable of development. Both were watched continuously under the microscope during their significant period of development.

It is obvious that if there has been a complete segregation of organ-forming substances in the unfertilized egg, a fragment containing only material from the animal half of the egg should be able to form no digestive tract and no skeleton (the larval skeleton being formed by the mesenchyme cells, which in turn are derived from the micromeres); and that a fragment of the vegetal half containing only potential endoderm and mesenchyme should be without ectoderm enough for a body covering. Similarly, if all the potential mesenchyme has been segregated in the region of the vegetal pole, the large fragment remaining after the removal of the vegetal polar region should give a larva in which no mesenchyme and therefore no skeleton would be formed.

Further, if there has been a complete segregation of organ-forming substances in the unfertilized egg and this material has a radially symmetrical arrangement around the axis of the egg, section through the poles along the axis should give two fragments that would form the same number of micromeres on each piece; four on each, if each cleaved as a whole egg; two on each, if each cleaved as a half egg. If the cleavage of the fragments were that of proportionate parts of the whole, the number of micromeres on each piece should vary with the degree of inclination of the plane of section to the axis of the egg.

The results of the experiments proved conclusively that neither size of fragment nor the region of the surface involved is of influence on the formation of primary mesenchyme. A fragment of about one twentieth the volume of the entire egg, taken from near the animal pole, the region farthest from that in which the localized micromere-forming substance may be supposed to lie, may give rise to a normal blastula with mesenchyme. The discovery of the fact that the formation of primary mesenchyme is not dependent on the formation of micromeres is merely incidental. Fragments that during their cleavage give rise to no micromeres, or to one or to two or to three or to four, may all give rise to larvae with mesenchyme. The important result of the experiments is the proof that prior to fertilization there has not been a complete segregation of either mesenchyme-forming or endoderm-forming substance and that a mesenchyme-endoderm-forming substance has a uniform distribution throughout about nineteen twentieths of the egg. The animal polar cap seems to contain only ectoderm-forming material.

The results do not cast doubt in any way on the belief that the material from which the mesenchyme is formed is ordinarily cut off in micromeres at the fourth cleavage. They do show that, after the removal of the region normally giving rise to micromeres, the cytoplasmic tradition may be carried on, and out of its undifferentiated store new micromeres developed to replace the material lost. What is of more importance is the fact that even though no micromeres are formed, mesenchyme cells may be produced, and a perfect larva formed. As a matter of fact, there is nothing new in this conclusion. Driesch and Zoja both came to the same result thirty years ago. Zoja's practically forgotten observation is of especial significance for the reason that the micromeres of the cleaving egg were removed with a needle from the sixteen-

cell stage, all four being isolated in such a way that there was no doubt of the observation. The remaining macromeres and mesomeres produced a perfect pluteus.

The statements made thus far indicate the totipotency or equipotentiality of different parts of the egg. In order that we should form no incorrect conclusions it is desirable that we should note that a certain volume of material is necessary for complete development.

Fragments of
1/75 to 1/50 the volume of the egg did not accept fertilization;
1/50 to 1/35 became fertilized, but did not cleave regularly;
1/31 to 1/24 cleaved regularly;
1/21 to 1/17 became blastulae with mesenchyme;
1/11 to 1/10 became gastrulae, and
1/4.4 = (5/22) became normal plutei

In other words, no fragments smaller than one fourth the volume of the egg reached the characteristic sea-urchin larval stage.

We may now go further and make specific application of our general statements concerning polarity and symmetry to other results of the series of experiments.

Very early in the work it became evident that in most of our fragments the first two planes of cleavage were at right angles to the plane of section and that the micromeres were formed on the surface of section at the intersection of these two planes. The place at which the micromeres appear becomes the posterior end of the blastula. It is therefore evident that in some of the fragments there has been a change in polarity. Following horizontal section there is no change in polarity in the animal fragment. In the vegetal fragment it has been reversed, shifted through 180°; in the fragments obtained by vertical section it has been shifted through 90°. A new axis has been established. No explanation of this phenomenon has been reached.

Concerning symmetry. In large animal fragments obtained by diagonal section the asymmetrical cleavage of the fragment suggests the persistence of an established plane of symmetry. The statement that the results suggest, but do not demonstrate, a bilaterally symmetrical organization of the egg is deliberately conservative. It is known that the eggs of many forms are bilaterally symmetrical. For the sea-urchin egg, however, the idea that symmetry is determined at the time of entrance of the spermatozoon has been generally accepted. That this may not be the full truth is suggested by the observations mentioned above and by the fact that sea-urchin eggs activated by reagents causing parthenogenesis also give rise to bilaterally symmetrical larvae.

Concerning the organization of the egg of the sea-urchin *Lytechinus* it may be said that the evidence shows that the egg has polarity and that the animal polar cap contains only potential ectoderm. The evidence suggests strongly a bilaterally symmetrical rather than a radially symmetrical organization. It also shows that such fundamental characters as polarity and symmetry may be established epigenetically in egg fragments.

The egg is a living cell in which one of the characteristic attributes of living cells, division, has been suspended. It has, so to speak, been withdrawn from an active existence. It remains in a state of inactivity until it is activated, in the normal course of events, by the entrance of a spermatozoon. The results of the entrance of the spermatozoon are two—the activation of the egg to development and the modification of the course of development in such a way that biparental inheritance becomes evident. The successful development of the Roux-Nageli-Weismann theory of the idioplasm has been possible because of the visibility of the phenomena of mitotic cell division. The intensive

study of the nucleus has been possible. No one has consciously lost sight of the fact that in the activities of living substance we are dealing with nuclear enzymes and a cytoplasmic substrate. Each is necessary to the other. The nucleus can not act unless it has something on which to act. The cytoplasm can not develop unless it is acted upon.

Conklin, in 1915, stated his conclusion that "the egg cytoplasm fixes the general type of development and the sperm and egg nuclei supply only the details."

A little later Loeb in "The Organism as a Whole" wrote,

> The most important fact which we gather from these data is that the cytoplasm of the unfertilized egg may be considered as the embryo in the rough and that the nucleus has apparently nothing to do with this predetermination. This must raise the question whether it might not be possible that the cytoplasm of the egg is the carrier of the genus or even species heredity while the Mendelian heredity which is determined by the nucleus adds only the finer details to the rough block.

In 1912 at Montego Bay in Jamaica I had the opportunity of studying the development of the sea-urchin *Cidaris.* In its early development this primitive sea-urchin is unlike any other echinoid that has been studied. The manner of formation of its mesenchyme resembles that described by Seeliger for the crinoid *Antedon* rather than that which we associate with the echinoids. The formation of mesenchyme occurs after gastrulation has begun, the mesenchyme cells arising from the inner end of the archenteron.

For a study of the early effects of hybridization this egg offered all the advantages of the crinoid egg. Two cross fertilizations were made, one with *Lytechinus,* the other with *Tripneustes,* both regular echinoids that form their mesenchyme early, *i.e.,* in the stage of the blastula. In both crosses the mesenchyme cells arose from the sides and around the base of the archenteron, close to the point of union of the archenteron with the wall of the gastrula. In point of time the appearance of the mesenchyme seemed slightly hastened, although not enough to warrant a general conclusion to that effect.

This result gave earlier visible evidence of the influence of the spermatozoon in the production of paternal characters than had previously been obtained. The reason for this lay wholly in the nature of the material. Material belonging to two visibly different systems of development was used.

Development of the hybrids proceeded regularly as long as it followed the general path of development taken by most echinoids. At the point of divergence of special from general, abnormalities appeared. An orderly series of developmental reactions had been disorganized by the introduction of foreign nuclear material. In 1923 in my report on this work I stated in conclusion,

> The normal development of the *Cidaris* egg is of a less specialized type than that of the eggs of the species whose sperms were used in the cross-activations. As long as the two courses of development lie parallel, we say that development is normal. When the point of divergence between the two paths is reached, characters appear which we call aberrant. Differentiation lies in a series of reactions between nucleus and cytoplasm. In attempting to superimpose a specialized on a non-specialized type of development we fail, because of our lack of ability to harmonize two disharmonious systems of development.
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> The consideration of this material emphasizes again the fact that the thing inherited by offspring from parent is the capacity for development. What that development will be depends on the interactions between nucleus and cytoplasm and on adjustment to the environment. The cytoplasm is the material that is shaped during the series of reactions. It is because of the fact that the cytoplasm of the egg is the material basis of the body that Conklin's statement that the egg cytoplasm "fixes the general type of development" is true.

A few moments ago, in describing the appearance of the egg, I said, "One may distinguish between living substance

(protoplasm), included materials (deutoplasm) and transitional stages between these two, each being the end product of a reversible reaction." This is a bold statement and demands proof.

It has not been possible to treat living material in a manner similar to that in which an organic chemist may treat crudes. The nature of living material seems to render that impossible. The determination of the chemical nature of the formed components, inclusions, in the egg should not be an impossibility. During the past three years with the help of two collaborators, my colleagues Dr. M. S. Gardiner and Dr. D. E. Smith, as well as that of both graduate and advanced undergraduate students, I have been attempting to reach a rational interpretation of the nature of the bodies that may be seen included in the cytoplasm of various cells.

The research had its foundation in evidence of the effect of foreign nuclear material on the cytoplasm of cross-fertilized eggs. Its first development was along the lines of an effort to determine the way in which yolk is transformed to living substance. Its status at present is that of a microchemical and biochemical study of biological material.

The study divides itself naturally into three parts: first, the study of the tissues; second, the chemical analysis of the tissues, and third, the study of the substances separated from the tissues, the latter part of the work being checked, so far as possible, by a similar study of purified commercial products.

Having done these three things, the opportunity for the comparison of the stained tissues with the stained separated substances is open.

The plan would be simple and direct if it were not for two facts. In the first place, similarity of staining reaction does not necessarily indicate identity of substance. Most of the dyes used as biological stains are "indicators" only in a limited sense. In the second place, there is no means of demonstrating that the substances obtained from the tissues are those that were in the tissues when the necessary manipulations were begun.

Eggs and ovaries of the sea-urchin *Echinometra* have been studied with vital dyes and have been preserved (fixed) with reagents designed to preserve included substances. This material has then been sectioned and stained with the dyes that are of use in the demonstration of formed components in the cytoplasm. The use of sea-urchin material is merely incidental. The use of this particular sea-urchin was determined because of the abundance and unusual staining capacity of its inclusions.

Material from the same source was preserved and extracted in strong alcohol, analyzed chemically and studied further. Nothing has been washed out and thrown away. Thus far the work has dealt with the fats and to a limited extent with the carbohydrates. Nothing has been done with the proteid content. The ether-soluble portion of the original alcoholic extract has been separated into its fractions. At each stage of separation these fractions have been studied with vital dyes and have also been made into emulsions which have been fixed, stained and studied as though they were animal or plant tissue, or have been floated as films on the fixing fluid and subsequently stained and studied.

A single example will be sufficient as an illustration. One of the formed components of the cell is the Golgi body, composed of a substance that reduces metallic salts, the metal (silver, osmium, etc.) being deposited in the Golgi body. The Golgi substance may be seen in the form of blackened droplets or rods, in the form of a vacuole whose rim is either completely or interruptedly blackened, or in the form of a vacuole containing a deeply blackened net.

Upon treating the young germ cell, before the accumulation of inclusions has begun, with osmic acid, no blackening effect will be observed. Upon treating a similar, but older, cell with this reagent, a diffuse blackening may be seen. In an older oocyte fine blackened granules may be demonstrated; later, characteristic blackened batonettes, and finally the Golgi body with its blackened network will be evident.

Similar observations may be made with the aid of certain vital dyes; Nile blue sulphate, for example, gives especially significant results. It stains pure neutral fat red and fatty acids blue. During the past few weeks its use has given us very significant results in the study of amphibian blood corpuscles and in cells of tissue cultures.

The same type of observation on the extracted fats, both with vital stains and following the use of fixatives containing osmic acid, has been made.

Step by step the fractions in which the blackening by osmic acid is not persistent were eliminated down to the residue containing neutral fats, cholesterol and fatty acids. The neutral fats are blackened by osmic acid, but osmicated neutral fat is readily soluble in turpentine, while the osmicated Golgi substance is resistant to solution in turpentine. One fraction after another was eliminated as not being the cause of the persistent blackening. The cholesterol was eliminated.

Finally within the last few weeks, after the study of the saturated fatty acids, the unsaturated fatty acids have been studied. These blacken almost instantaneously with osmic acid. They resist extraction or solution in turpentine. With them every stage of Golgi body that has been demonstrated in fixed tissue can be duplicated.

These are facts that have great significance when applied to any cell in which a process of storage or of secretion is taking place. (The Golgi body is characteristic of such cells.)

The growing oocyte is not an isolated, independent cell. It is part of the body whether attached to the ovarian wall or floating in cœlomic liquid. Materials for its growth are supplied to it from the surrounding medium.

The point to be made will be clearer if we digress for a moment and consider the processes of digestion and absorption of fats in the body. During digestion, hydrolysis of fats into glycerine and fatty acids occurs. These are absorbed separately and recombined in the cells of the villi of the intestine to form fat, the ester or salt of fatty acid and glycerine. The histological evidence just presented to you indicates that the same process is taking place in the growing oocyte.

We know that the particles actively concerned in the vital processes of the cell are of a size beyond the limits of observation with the microscope. Products of their activity become visible only when the granules of product come above this horizon.

The whole picture of accumulation of osmic blackened substances in the growing egg is that of synthesis of fats. The diffuse cloud, the formation of fine granules, of chains of granules and finally of larger droplets are the visible expression of one series of vital processes, processes that may be correlated by direct observation, with the interaction of nucleus and cytoplasm.

The same type of evidence that has been given for the Golgi substance may be given for the phospholipins, whose visible expression is in the chondriosomes or mitochondria. Both Golgi substance and chondriosomes may be looked upon as transitional between inert and living substance.

These are facts. The method employed in their demonstration has been direct. There seems to be one logical conclusion.

THE NEW FERTILIZERS

By Dr. W. S. LANDIS

The Origin of Agriculture

True civilization began with the discovery that when certain varieties of seed, known to possess food value, were sown upon upturned soil, they reproduced themselves multifold. Such a food supply, and of considerable reliance, required a more or less fixed abode and gave opportunity for thought and study which are the basis of our civilization.

Throughout the Stone Age man was a hunter and savage, gaining his food solely from the chase. These first truly human beings hunted the wild grasslands in packs, the men and women sharing alike in the pursuit and its products. The cares of maternity at times caused the women to drop out of the hunting party for short intervals, later rejoining it again and with their offspring if the latter survived. By degrees more and more attention was paid to the raising of the young, and the detachment from the hunting party was for longer intervals. The women established at least temporary homes to which the hunters would return at intervals with their catch.

This development in turn restricted the active hunting area, and with increase of population of the crude settlement, due in part to proportionately greater survival of the young, game naturally became scarcer and the chase sterner. The women gave more and more time to the household and the children, and the chase called for more and more skill and endurance. The female eventually dropped entirely out of the chase and left food supply to the male.

Were the chase only moderately successful, or the male kept away too long, the generally scanty stores of food would be exhausted and the women and children face starvation. Thus necessity probably drove the women to supplement their meat diet with nuts and berries, and, finally, in extreme desperation, with seeds and roots collected near the habitation. Our first vegetarians were undoubtedly the women and children.

Such periods of great stress must finally have forced the eating of edible seeds of the wild grasses and the primitive grains on the male. His meat diet probably persisted longer than with the female. It is possible that climatic changes were responsible for some of the great rainfall and of subnormal temperatures.

A further stage of development and at a much later date, characterized by the domestication of animals, furnished a more assured meat supply, but apparently did not alter appreciably the earlier acquired vegetarian habits. These pastoral peoples, following their flocks to the fresh pasturages, moved but slowly. The wild grasses and primitive grains still furnished a portion of the food supply. Coincident with this pastoral development, but not necessarily parallel, we find our first evidence of agronomy. There are reasons for believing that agronomy was practiced before animal husbandry in Mesopotamia, but the reverse is indicated in other centers of early development of the human race.

We can only theorize as to the actual beginnings of grain growing. Settlements of some permanence must have been customary, for a very considerable part of the year is required for the reproduction of a seed of the type of the wild grains, as emmer, wild rye, millet, etc. It is not unlikely that an accidental

spillage of seeds being carried into the more permanent home showed the way. More plausible is the explanation that the wives decorated the graves of their deceased husbands with food and flowers, and seeds among the food-stuffs dropping on the newly upturned soil covering the grave sprouted and grew luxuriously. Bearing out this latter theory is the practice repeatedly discovered in various parts of the world of finding the early grain patches around graves. Later a corpse was always buried in the grain field, usually in a corner. If such corpse was not conveniently at hand at seeding time, a victim was sacrificed for the purpose. With the progress of civilization an animal carcass was found to be quite as efficacious, and the ritual of animal sacrifice at planting time persisted for a long, long time.

Exact dates can not, of course, be established for such beginnings. It has been established with reasonable exactitude that grain was grown in Egypt before 4000 B. C., and in Mesopotamia still earlier, certainly before 5000 B. C.

The place that the woman played in this development has been recognized from the earliest times. We need but turn to our mythology for a long list of goddesses of agriculture, of the harvest, etc.; from Asia Minor, Agdistes, Cybele and Dindymene; from Egypt, Nysa and Isis; from Greece, Rhea and Demeter; from Rome, Flora, Ceres, Ops. There were no males so commemorated.

Fertilizers and Manures

It seems a long stretch of the imagination to look upon the early planting on and around the graves as a primitive attempt at improvement of yield through plant feeding, yet the practice of human and animal sacrifice may have had behind it such a basis.

To-day it is the most common knowledge that seeds reproduce themselves when planted in cultivated soil. We learn quite early in life that the plant draws food from the soil, and the soil soon becomes exhausted if such food elements are not replaced. Around this has grown our practice of manuring or fertilization. Let us for a moment get a clear understanding of these terms. The word "manure" is the older. It once had a much wider significance than it possesses to-day. Originally it meant "to work by hand," and much later acquired the more restricted meaning of "a material or process for the betterment of the soil." It was not until the seventeenth or eighteenth century that further limitation of meaning took place, and its use became generally restricted to materials used in such betterment of soils. At first even in its most narrow of the above senses it included chalk, gypsum and lime as well as what we now call "farmyard manures." We now apply it to this last-named material alone.

The term "fertilizer" is of comparatively recent origin. In general it is applied to materials which were presumed to feed the plant directly, in contradistinction to the "manure" which only indirectly fed it. Nitrates, ammonia salts, phosphates and potash salts were believed to be better classed under this newer term "fertilizer." But the end of such reclassification is not yet in sight, for within the past year the manufacturers of the common chemical or commercial fertilizers have objected to the use of the term "fertilizer" for their products and are advocating instead "plant foods."

On the subject of agronomy, which includes that branch of agriculture devoted to the growing of the crops and in particular grains, fruits and vegetables, we still have a great deal to learn of the fundamental and underlying facts of plant feeding. We know that seeds when planted upon certain types of soils

will under favorable climatic conditions reproduce themselves many fold. We also know that when this same operation is repeated a number of times on the same plot of ground the successive yields become less and less and finally seem to reach a certain fairly definitely fixed minimum of return. We can improve the return by using better seeds and there has been marked progress made in seed development. By rotation of crops, that is, the successive planting of seeds of different families, the decrease of productivity can be halted to a marked extent. By the use of addition agents to the soil crop yields can be maintained or even improved. Knowledge of the use of such addition agents goes back probably to the very early days of agriculture. The use of animal excrements dates before the dawn of recorded history. The earliest writings of the Romans mention the value of dung, of which Virgil sang. Varro and Columella, the earliest agricultural writers, mentioned not only the use of farm manure, but of marl, and spoke of the effect of green manure upon the succeeding wheat crop.

There seems to have been a gap left in the literature of fertilization during the Dark Ages, and it was not until the Renaissance that writings upon agriculture became common. There was no mystery in the use of farmyard manure, marl, lime and ashes for promoting crop growth. Just when the Indians of New England learned to place the fish in the corn hill is not recorded. Undoubtedly all these early fertilizers and manures were accidental discoveries.

The first real scientific basis of our modern practice dates back to the great chemist Liebig, approximately ninety years ago. Liebig probably originated very little, but he reduced the great mass of experience of his predecessors to an exact quantitative basis. His careful analysis of the constitution of the growing plant, showing that 95 per cent. of the dry matter of the plant was derived from the atmosphere and only 2 or 3 per cent. was drawn from the mineral constituents of the soil, threw an entirely new light upon plant feeding. His early work was followed immediately by comprehensive experimental work, the most noted of the early beginnings being that of Sir Joseph Bennett Lawes, who began systematic experiments on the family estate at Rothamsted, which estate is now our most celebrated agricultural experiment station.

What we now consider as most typical of our fertilizer materials did not, however, originate with Liebig. As early as 1653 English publications showed the value of rags, wool, bones, horn and wood ashes. A few years later blood, hair, feathers, hoofs, skin, fish, malt were added. Twenty-five years later the value of niter or saltpeter as a fertilizer material was recorded. Fifty years later soot and wood ashes, oil cake and grain dust were added to the list. It was during the nineteenth century and probably contemporaneous with Liebig's work that the greatest developments took place. Chile nitrate and Peruvian guano were imported into Europe for agricultural purposes. Practically at the same time, 1842, the first superphosphate patents were taken out, and a year or two later superphosphates began to appear on the market. The potash salts were added to the list in 1860 with the opening up of the Stassfurt beds. At about the time that nitrate first came into the European market, sulphate of ammonia also appeared in quantity and was tried in agriculture.

Liebig's analytical work confirmed the presence of nitrogen, phosphate and potash in appreciable quantity in the living plant. The early fertilizers and in fact most of those compounded even to-day base their principal value upon these three ingredients. Our knowledge,

however, of the constitution of the plant shows that it contains practically every known element, some, it is true, in extremely minute quantity. The soil itself is an extremely complex material. Most of the elements found in the plant are derived from it, for the living plant draws little besides carbon and nitrogen from the atmosphere and very little of the latter directly.

Plant Foods and Plant Stimulants

It is probably unwise to take the broad view-point that a fertilizer is any material which is added to the soil to increase plant growth and crop yield. Such definition is too comprehensive. An increase of yield may be due to one or more of several factors. Growth may be promoted by feeding, in which case our fertilizer should contain the necessary elements which, when absorbed by the plant, promote growth. Nitrogen, potash, phosphate, manganese, zinc, vanadium, titanium and a host of other elements would come under this class.

We recognize that bacterial action plays an important part in rendering soil constituents available for absorption and conversion by the plant. Bacteria are rather particular about the kind and conditions of their surroundings. If we can promote the development of bacteria which in turn converts our soil constituents into more available food, we usually obtain response in growth. We may, therefore, add to the soil conditioners such as lime, and bacterial foods such as manures and organic matter which promote the development of these colonies of valuable assistants. Such materials would not necessarily come under the class of plant foods but rather as conditioning agents or bacterial foods.

Of recent years we recognize still a third method of increasing plant growth, which we class as seed stimulation. We are not so clear as to the function of this group of materials, but apparently they act in much the same way as the tonic which the physician gives us when we are not quite up to par. In general the seed itself is treated with these reagents, resulting in a quicker sprouting and more elaborate development of root structure and a material increase in growth and yield. Here again we have crop improvement without the addition of a plant food or soil-conditioning agent. It is more a stimulating effect forcing the sprout to develop an abnormal root structure capable of picking up from the soil a correspondingly increased quantity of latent plant food. In view of the complexity of these three very widely different phenomena I am inclined toward the present tendency to drop the word "fertilizer" as applied to our commercial product containing nitrogen, potash and phosphate and use instead the more descriptive term "plant food."

Present-day Plant Foods

The practice of preparing and using artificial fertilizers differs in various parts of the world, just as general agricultural practice differs. In some localities the individual materials which the farmer had determined most suitable to his needs are purchased and applied singly to the soil. This practice received its highest development in Europe and persisted up to recently, at present showing a tendency to a change to the practice of using a compounded or mixed fertilizer. In the United States our practice has been the reverse and the plant foods have been assembled and mixed at a centralized factory, and one application is made of the composite material. Even here there has been a tendency to buy the ingredients and assemble them on the farm, but it is probable that we will see a return to the older practice with the advent of the newer fertilizers. The choice is largely a question of availability which in most cases means cost of labor.

Liebig's work demonstrated that nitrogen, phosphorus and potassium were the most important constituents of the plant structure that of necessity had to be supplied to the ordinary soil to maintain the crop yield. Soda, lime and silica, while important constituents, are present in sufficient quantity in the usual soil to present no problem of exhaustion. In view of the very wide variation of cultivated soils throughout the world it must be remembered that there are always some exceptions to any such general statement. Upon this foundation our fertilizer practice arose. Such materials as nitrate of soda and sulphate of ammonia, being available in quantity, formed the nitrogenous portion; mineral phosphates found in various parts of the world by suitable chemical treatment could be rendered soluble, and the processing of these materials took care of the phosphorus requirements; the discovery of the potash salts in Germany and later in France, Poland and Spain formed the basis of the potash constituent. In addition there have been vast quantities of otherwise wasted products, such as refuse from the slaughter house, oil cakes and meals from the oil factories, hair, wool and leather scrap from various sources, all of which contain valuable plant foods in more or less available form or if unavailable can be simply processed to make them acceptable fertilizer materials. In the case of certain slaughter-house products and oil meal cakes, these products which years ago found their only outlet in the fertilizer industry have now found application as stock foods, and vast quantities have been diverted from the fertilizer to the feeding industry.

The fertilizer industry has in consequence come to depend more and more upon chemical products for its raw materials. The natural nitrate of soda and the by-product sulphate of ammonia, to which have been added of more recent years various synthetic nitrogen chemical products, such as cyanamid, nitrate of lime, urea and ammonium phosphates, now form the bulk of our nitrogenous ingredient. There is little chance of return to the waste organics, and with better education of our farmers the little still used will further decrease.

The phosphate industry still relies largely upon the natural deposits of phosphate rock for its raw material; processed with sulphuric acid this has appeared upon the world markets as superphosphate. Processed with phosphoric acid a more concentrated form of soluble phosphate has been produced, but up to the present the quantity of the latter used is only a small fraction of the former. Within quite recent years the raw phosphate rock has been used for the production of phosphoric acid either by chemical or electrothermal processes, and this phosphoric acid has been treated with ammonia or potash to form the corresponding phosphate salt.

There has been little or no change in the potash industry which since its inception has turned out various grades of chloride of potash or sulphate of potash.

The American Mixed Fertilizer

Here in America, where labor costs are high and extensive farming is practiced, it has been customary to supply to the farmer the three important plant foods in a compounded or mixed form. The processing may be simple or complex, depending upon the raw materials used in the preparation of these fertilizers. In its simplest form it consists of a mere mechanical mixing of various purchased ingredients to meet a definite formula. In its more complex form less available nitrogenous materials undergo a chemical processing, usually in the presence of phosphate rock, forming a semi-manufactured material. This in turn is mechanically mixed with other raw materials to form the complete fertilizer.

These American mixed fertilizers contained as little as 10 per cent. of the plant foods, ammonia, phosphoric anhydride and potassium oxide, which are the chemical names for the more common designations, ammonia, phosphoric acid and potash. Most of such low-grade products have been legislated out of existence within recent years and very few fertilizers that appear on the American market contain less than 12 per cent. of the plant foods, ammonia, phosphoric acid and potash. The tendency to-day is to produce materials running from 14 to 16 per cent. of these ingredients in the bulk of the fertilizers turned out.

Quite recently there has appeared on the market the so-called double strength or double formula fertilizers containing from 20 to 30 per cent. of plant foods.

This American practice of mixing the important plant foods together in a factory and selling the resultant mixture to the farmer had long been frowned upon by the European agriculturist. The basis of his criticism was that this system was forcing the farmer to purchase materials which he really might not require, and that a better principle was to analyze the soil, determining the lacking plant foods, and then supply only such deficiencies. No objection can be taken to the theory behind such a procedure, but in practice it did not always work out successfully. The taking of accurate soil samples is a complicated procedure. The analysis is long and tedious. The interpretation of results is very difficult. A high-pressure salesman falling upon the farmer at purchase time forced the sale of his single ingredient, and for one of several reasons the farmer usually bought a most unbalanced fertilizer. Now the plant is not able to substitute to an unlimited extent one plant food for another. If a surplus of nitrogen is present a plant thrives only to the extent of the most deficient of the other important foods, as, for example, phosphate or potash. It avails very little to supply large quantities of nitrogen without adequate amounts of phosphate and potash. At the close of the war there were in existence in Europe enormous factories built during the war for the supply of nitrogen for munitions. At the close of the war these plants turned to the production of fertilizer nitrogen salts and forced their product upon the home markets with the result that there was only a temporary increase in food production, and crop yields gradually dropped off in spite of the continued enormous consumption of nitrogen. A comprehensive study of the situation showed the trouble to lie largely in deficiency of one or more of the other plant foods, and a complete change of manufacturing program was embarked upon with the object of producing a complete fertilizer containing the three plant foods balanced at least to the extent of insuring a fair crop yield. In other words Europe today is adopting at least in principle the old established American practice of furnishing the farmer a mixture of three important plant foods in proportions to insure at least fair crop returns.

The New Fertilizers

As mentioned above the fertilizer industry, more particularly in this country, developed first around a practice of using a great mass of waste materials. Most of such materials are of comparatively low analysis, and when they contained any quantity of nitrogen, such as the better grades of cotton-seed meal, animal tankage, fish scrap and the like, they found their way into the feeding industry, leaving only the lowest grades for fertilizer. As a result of this use of very low grade, or more properly speaking low analysis materials, the mixed fertilizer produced contained a comparatively small amount of plant food. Twenty years ago we began to extract nitrogen from the atmosphere and con-

vert it into chemical products and to-day more of such so-called synthetic nitrogen is produced than comes from the by-product coke-oven and the nitrate fields of Chile. Most of the synthetic nitrogenous compounds produced are of comparatively high analysis. The processes of production themselves are rather flexible, enabling one to obtain the chemically combined nitrogen in several concentrated forms. There is a widely diversified field into which the primary products of these fixation processes can be diverted. It has, therefore, appeared logical to maintain the concentrated characteristics of these new synthetic compounds and with them to produce much more concentrated fertilizer. As a consequence there are on the markets to-day complete fertilizers containing 40 per cent. and upwards of the three plant foods. The whole fertilizer world is actively engaged in research along these lines, and we may expect in the future to find still further new combinations lending themselves to the production of these concentrated or high analysis products. In general these materials are of the types of ammonium nitrate, ammonium phosphate, potassium phosphate, potassium nitrate and like combinations. The underlying principle is to eliminate so far as possible the non-plant food ingredients.

Distribution Problems

The distribution of fertilizer is quite a problem. The various products formerly used came from widely different sources. They were assembled in mixing plants, bagged, tagged and guaranteed as to content and then transported to the farm centers. Further transport to the farms was then required and finally distribution in the fields. The costs of assembling, bagging and transportation to the farm centers in many cases equaled the wholesale value of the plant foods contained, so that the practice was not particularly economical in the case of the low-grade materials. The actual costs of field distribution alone formed a very appreciable item where the material contained only 10 or 15 per cent. of plant foods. With the advent of the higher grade materials analyzing three or four times as concentrated as the older types these distribution costs could be cut materially. From the economical standpoint there is, therefore, a marked advantage in increasing concentration of the fertilizers.

The older fertilizers made up very largely of a slightly soluble phosphate mixed with the insoluble organic nitrogenous materials and with only a modest quantity of soluble salts offered no great problem in field application. The minimum of care and the use of the crudest equipment enabled the farmer to avoid damage or burn. The new high analysis fertilizers, however, are essentially water-soluble materials. Their application, if injury to the growing plant is to be prevented, requires more care and in particular a more thorough incorporation with the soil before or during seeding. They must be located more carefully with respect to the seed. The economical quantities used are much smaller than with the low analysis materials, and require equipment capable of fine adjustment. None of these problems, however, is insurmountable, and my staff has planted hundreds of plots over the past three years with fertilizers containing as much as 60 per cent. of plant food and all in water-soluble form, using the better standard grades of available farm equipment without difficulty or damage.

There is still another phase of the new fertilizer situation which is now commanding our best attention. I mentioned earlier the fact that careful analysis of the plant showed it to contain a very wide variety of elements, and it is believed that most of these play a vital

part in the growing plant. In the old days most of the waste products used were of plant or animal origin and contained many of these essential elements. Phosphate rock itself is a most complex material and in the process of manufacturing superphosphate the whole of the rock appeared in the superphosphate, so that fertilizers compounded of these materials contained most of these vital elements even though in extremely minute quantity. Many of the newer fertilizers are crystallized products, that is, chemical products crystallized from solution and in the process of crystallization purified or freed from contaminating elements. The disappearance of the organic wastes from our fertilizer materials leaves out another source of supply of some of these rarer elements. In consequence the agronomist is now faced with a new problem and must be on the eternal lookout for elemental deficiencies of more or less unsuspected nature. I have in mind the case of the Florida soil which refused to produce tomatoes until a small quantity of manganese was added. I also have in mind two other cases where zinc in one and titanium in the other were necessary to successful agriculture. I believe, therefore, that we are opening up a new field of investigation of the influences of new elements, which influence has not been felt on account of the older fertilizer practice, but which may show up in a substantial manner in the case of some of the new fertilizers such as are being produced in Europe. It is a subject to which some of us are paying the closest attention.

Summary

Summing up, the future fertilizers will be much more concentrated in the three common plant foods than even past history would lead one to suppose. The older organics of animal or vegetable origin will disappear to still greater extent and will be replaced by newer synthetic salts mostly of inorganic nature. There is no particular advantage from the agricultural standpoint in these organics and the newer products will produce equally good or better results. Education of the farmer in the use of the newer synthetic products will decrease the demand for the organics to that point where they sell at an equally competitive price.

There will be a material change in the character of the inorganic fertilizer materials, and those showing tendency to deflocculate soils, others showing tendency to leave harmful residues in the soil and those of inferior physical characteristics will disappear and be replaced by greatly improved combinations. Many new elements will be added to the list of essential plant foods. Process limitations existent to-day will disappear in so far as they eliminate essential plant foods, and the science of compounding will be greatly elaborated as we require better knowledge of plant requirements and soil deficiencies.

The dream of the concentrated synthetic foods of the human race will be realized first indirectly through supplying a similar material to the soil and letting nature carry on an intermediate transformation.

SCIENCE AND EDUCATION

By Professor WILLIAM D. TAIT

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"As civilization advances poetry necessarily declines." Leaving aside the literary significance of that statement, it must be admitted that when poetry was the *sole* expression of man in relation to his surroundings he was untutored, unlearned and uncivilized. As he advanced, when he came to know more about his place in the scheme of things, in a word, as he became more civilized, he found other and more exact means of expressing his relation to the world of nature. This refinement of expression is synonymous with scientific progress. Science then means a better and more exact knowledge of the world we meet with day by day. Mankind is no longer at the mercy of nature. Nature is now a servant, not a master.

Man's advance in civilization is thus to be measured in terms of the nicety of adjustment to his environment, or to put it otherwise, his efficiency in meeting his environment is the measure of his civilization, and the records of this advance are to be found in the annals of science. This increased efficiency can only come about by man's knowing more about the world in which he lives, no matter whether it be the so-called outer world of nature, his fellowman or even himself. Progress in civilization or towards civilization, if we admit such a thing, depending on efficiency and this efficiency depending on knowledge, the conclusion is that civilization depends on knowledge. However, it is a mere platitude to say that progress depends upon knowledge. When we speak of knowledge in this context we mean scientific knowledge, the sort of knowledge which consists of facts grouped in what are known as scientific laws which are exact statements of facts, not general hearsay or opinion, or knowledge in the vague sense, but exact, detailed and careful knowledge. These laws can be used for our advantage or disadvantage, and upon our wise use of them depends our progress.

The desire to be master of his environment led man to become a scientist and the beginning lay in magic. Doubtless this depended then, as it does now, on certain innate tendencies called instincts, and the two which probably play the greater part are curiosity and pugnacity. As long as myth, superstition and poetry were found sufficient and satisfactory, just so long was man at the mercy of his environment. All this changed as his curiosity and pugnacity bore fruit. At first, this inquiry was confined to the outer world, and thus one of the oldest sciences is physics, but the success there and the impetus thus gained has led science into all fields with the same productive and beneficial results to man and his problems of living. Much to the surprise, and contrary to the a priori speculation of some, including Kant, we have to-day a science of mental life which in general employs the same methods as the other and older sciences. The step of psychology has been very rapid because it found method and instrument ready to use and was thus relieved of much of the pioneer work which fell to the lot of the others, not the least of which was the overcoming of prejudices.

Simple as the statement may appear that science enables man efficiently and competently to meet his environment and

thus make progress as a civilized being, yet it has some profound and far-reaching consequences. It means, first of all, that we are, as yet, only at the beginnings of science, and it means, too, that in the struggle for existence, which struggle is unending, the individual or nation or race which knows most about the conditions to be met and the way to meet them, in other words, the one with the best scientific equipment, is the one which will survive. That inexorable law of selection still holds, but in a very intricate, refined and subtle way. Ignorance spells non-adaptability, failure, defeat and submergence. In yet another sense, it signifies that the days of the gentleman scholar, the amateur scientist, the man of general culture, are numbered, because the equipment which these individuals represent is insufficient and therefore inefficient even at the present time and will be increasingly so in the future. It signifies, further, that the periods to come in world history will be periods of specialized thinking, which may mean, in a way, the sacrifice of the individual. Yet it is only by such rigid scientific procedure in all the affairs of life that a people can become and remain efficient and cultured. A nation whose educational system is founded upon merely individual attainment, where each one thinks he knows something of everything and not much of anything, is doomed in a modern and ultra-modern environment. We must stand for corporate and national efficiency, and to do this well and thoroughly we require an intricate and accurate knowledge of our world which only scientific specialists can give. Hence we must have specialists in chemistry, physics, physiology, biology and in all the various aspects of life.

Some, of course, will see in such a thorough application of science to the affairs of life a merely utilitarian attitude, as if that were the deepest curse which could be uttered. For those who have a wider outlook and greater vision, who see life in its deeper parts, who see truth and beauty in all things, the word utilitarian has no such connotation. Mill did not use the word in this bad sense, and if his critics have been so narrow-minded as to do so, then the odium rests with them. The word should mean, and does mean, any truth which will help us to live and live better. It means the best in order to survive, and that means efficiency of reaction in the widest and best sense. In fact, the terms utilitarian, efficient, good and true are not very far asunder when looked at from the point of view of service to humanity. What other test have we for our ideals? Name it, reduce it to its lowest terms, and you have efficiency. It is the capacity of doing the right thing at the right time, and doing it well.

There are those, too, who think that science and culture are opposed, who are convinced that all culture and humanity are contained in the writings of Greece and Rome, or in works based on them. Such people fail to see that the scientific position not only includes the so-called classical, but is its foundation. Without science and philosophy (for philosophy is the mother of science) the world would be without many of the classics. When we read our Democritus or Plato or Aristotle we are reading the scientific speculations of their age. This goes by the name of culture with those who refuse to extend the same courtesy to the speculations and researches of modern science. Future ages will do as we do with the past—they will read our science and philosophy and the classicists of the day will call it culture. However, this is only one way of looking at the question. It is to be further remarked that with some of this mode of thought, culture is a much-abused word

for a rough smattering of scientific and literary information on many things, and a real, useful knowledge of few, if any. These people are accustomed to pride themselves on their breadth of view and their wide outlook, but it is a breadth based upon superficiality. Nothing is more deceptive than such a position. No man is really so narrow as the man thus beguiled and lulled into the belief that he is of some value. It is the specialist who has the broad outlook, the deep insight into nature, who can give a reason for his open mind and who has knowledge and fact to support his point of view. (Even archeological research is becoming more and more dependent upon science in the narrow meaning of the term science.) From this type we are belabored about the futility of scientific research. This criticism is not new, for the modern dilettante in culture copies it from the Greek poets whom Plato anathematized. One of their favorite witticisms is to compare such research (here they are again not original) to the waste of energy, as they think, in estimating the height of a flea jump. The answer to an attempt to laugh at science is to say that the point has been missed, for modern scientific work is infinitely more detailed and complicated than a flea or his jump. It is just this exact sort of thinking that has raised man to where he is, and has made of him the controller instead of being the controlled. No race or nation which relies upon amateur scholarship, which looks down on the methodical searcher in the "mud" of facts, by his results upsetting many a fond tradition; no race which stands for general scholarship to the exclusion of special scholarship, can hope to win in the struggle for survival either intellectually or politically. It does not require much wisdom to draw the conclusion that political supremacy will be a consequence of intellectual supremacy. Past supremacy was due to mere physical force, but future supremacy will depend upon brain force. Our existence then depends upon our education. This increased predominance of intellect will hold true, no matter whether it is applied to the manufacture of explosives or to preparing an argument for the League of Nations. There was a bygone age when the rough and ready could win, when one man could know enough of all matters to be expert in them all; but that is past, and it is for us to realize this, that we may equip ourselves the more adequately for the conditions which we now face.

II

We have spoken of efficiency in general and the part that in general education should play, but the principle is not different when we come to discuss the particular case, when we speak of educational methods, when we inquire into the relation between teacher and pupil, as to how much the teacher or educationalist should know about the mind of the child, about economy in school-work, the means to get the best work with the least expenditure of time and energy. All of this is vitally important because the foundation of a nation's greatness lies in her schools—especially the primary schools. Thus it is right and our moral duty to make sure that the best and proper methods are used. As scientists we should insist at the very outset that common-sense methods, custom, tradition, speculation, superstition, mysticism and theory should give way to scientific method.

Now all the various sciences deal with some aspect of experience. Physics treats of one aspect, chemistry of another, psychology of another, and so on. They differ more as regards point of view than anything else. More particularly, physics in the large deals with what is usually and perhaps erroneously called the outer world, while psychology deals with what is usually and perhaps erroneously called the inner world or

mental life or the world of personal experience. This distinction is not an absolute one, for every experience of the outer world is at the same time an inner experience. The same fact may, therefore, be a subject of investigation for both physicist and psychologist. Psychology, then, is a study of experience from a particular angle or point of view.

There was a time when psychology, or what was then called psychology, speculated about mental life, but to-day the psychologist is coming to rely more and ever more upon experiment, or controlled observation. What is not the result of experiment is to be considered as in the doubtful class or category. It is now by experiment that we study sensation, perception, memory, association, emotion, feeling, volition. According to experiment we study differences between individuals of the same group, or different groups, compare the adult with the child and find out significant differences which should be an aid in educational method. By experiment, we ascertain how children differ with regard to the various mental processes and in intelligence. We find, for example, that those who learn quickly learn best, that the child has not the same capacity of forming abstract ideas as the adult—which should persuade us to leave science and mathematics and perhaps some aspects of history till the university age. We find that children have a good memory for isolated impressions, such as words, which would indicate that language should be studied in the early years. We are also impressed by the fact that English composition can be taught just as well by writing about the history or geography of a place as by paraphrasing some idiotic story. In this way much time that is wasted might be utilized to good advantage. The same holds good with regard to the teaching of English grammar, which is best taught by not being taught at all. The failure of modern methods is here very apparent. By simple tests we can separate defective, retarded, normal and bright children, and thus provide a better opportunity to each class. Extensive studies have also been made on reading and writing which should be available to every qualified teacher. By experiment then we are potentially able to note the whole progress of mental life until it attains maturity, and we can even compare it with the animal mind in the same way. All of this can be done with exactitude, for the psychologist has at his disposal both instruments and methods. In short, we can find out the facts of mental life in place of speculating as to what they are or ought to be in the light of some preconceived theory or speculation.

This latter tendency has come to us through philosophy and has produced something of a misunderstanding and thus accounts for some lack of progress. In this case psychology is identified with philosophy. The philosopher is considered a psychologist. This has been productive of much confusion in educational procedure and method. Some of this might have been true a century ago, but not to-day, and it is becoming more apparent that those who continue to think so are behindhand in their thinking. To-day, psychology is one of the experimental sciences, while philosophy is not. The two studies require different method, different type of mind and different preparation. Psychology, like any other science, is an intensive study of a small part of experience, while philosophy is an outlook on the whole. Psychology is an application of the experimental method to mental life; philosophy is anything but that. Quite true is it that psychology was once a branch of philosophy, but so were the other sciences, and now psychology bears the same relation to the parent as do the others. The facts and laws ascertained or formulated will have the same value for philosophy

as those of the sister sciences, but such value will needs be estimated by the philosopher himself.

The result of this comparison between science and philosophy was, and is, that exactness, certainty, uniformity in the good sense, were at a discount. In place of this, the application of scientific exactness to educational method means that in place of speculation, tradition, custom, common sense and chance we shall possess certainty, progress and efficiency, for in proportion as we utilize the facts and laws as revealed by psychological research just in proportion will we be on safe and secure grounds. The mind, both of the adult and the child, must be investigated from the point of view of education, and we must be wary about taking the results of general psychology. In other words, we require an applied psychology just as we have an applied physics.

In some antiquated nooks one hears some murmurs about the return to the old discipline and the old methods. The main argument advanced is that the new ways are failures. True, mistakes have been made, but mainly in attempting to graft new ways to old, to pour new wine into old bottles. It is to be frankly admitted, in all fairness, that some of the so-called modern ways are just as flimsy and superficial as some of the old, by reason of the same speculative foundation. No one objects to the old discipline, and modern psychology upholds some of it, giving it a new and important meaning, but although we believe in discipline, we are not thereby committed to the crude old methods of obtaining that result.

Now it is not for the teacher to accumulate all the psychological material available, nor is it the duty of the psychologist to make breakfast food for the teacher. The responsibility for this lies with the educationalist, for this is his business and proper function. It is also his duty to investigate particular and special problems or suggest them to the psychologist. With other words, the educationalist is the clearing-house between the psychologist and the teacher, just as the engineer is the clearing-house between the physicist and the artisan.

There is another side to this problem, albeit a vanishing one. Just as some will object to science as a whole, so there will be objections to the application of psychology to education, because of the delusion of materialism in some minds that it may mean doing away with aims and ideals and purposes, that it will detract from the glory and dignity of man, that education will lose its halo, its sublimity and its idealism. Let it be answered that science does not presume to set up ideals (they are the result of social contacts), but it does presume to provide us with the best methods of attaining our ideals, however formulated. Without science, ideals are merely potential; with science, they become actual.

The age of non-science is past. When our teachers, our educationalists and our university leaders come to realize that educational method must be placed upon a firmer and more secure basis than that afforded by mere speculation and common sense, when they consider it their duty to investigate every problem connected with educational method by exact experimental methods, then we can say that the teacher, of whatever station, belongs to a profession worthy of the best. Until then all our vaporings about ideals are vain and useless. Experimental pedagogy is the pathway to ideals in educational method—there is no other. Science is thus the true altruism and the true humanity, because it works as no other way. "Ever not quite" must be the slogan of educational as of any truth. Test all your customs, for their working value is the measure of their truth. Experiment performs this test more accurately and quickly than chance observation and experience.

MAN AND HIS CLIMATIC ENVIRONMENT IN THE TROPICS[1]

By Professor ROBERT DeC. WARD

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WHEN the tropics are mentioned, most persons, I feel sure, picture to themselves a tropical island with waving palms, a white beach of coral sand, and the blue sea beyond; or a wonderful tropical night, with the moon shining in a clear sky and the soft breath of the trade wind rustling the leaves. Poetry and romance seem inevitably to be associated with the tropics. Such idyllic spots do exist, it is true, but they form only a small portion of the tropical zone as a whole and are actually far less typical than the vast grim deserts or the wide open spaces of the grasslands or the dark and gloomy forests.

Within the tropics, under the equatorial sun, and where there is abundance of moisture, animal and plant life reach their fullest development. Here are the lands which are most valuable to the white man because of the wealth of their tropical products. Here are the tropical "spheres of influence" or "colonies" which are among his most coveted possessions. It is in this belt that food is provided for man throughout the year without labor on his part; in which frost and drought need not be feared; where shelter and clothing are so easily secured, and often so unnecessary, that life becomes too easy. Nature does too much; there is little left for man to do. The simplicity of life, so far as providing food is concerned, has been emphasized by many writers. We are told that two days' work a week is often enough to enable a man to support a family, and that a month's labor will provide for a Malay more food than he can use in a year. Captain Cook put the case very emphatically when he said that a South Sea Islander who plants ten bread-fruit trees does as much towards providing food for his family as does a man in northern Europe who works throughout the year.

In a debilitating and enervating climate, without the necessity of work or the incentive to work, the will to develop either the man who inhabits the tropics or the resources of the tropics is generally lacking. Voluntary progress toward a higher civilization is not reasonably to be expected. The tropics must be developed under other auspices than their own. "Where nature lavishes food and winks at the neglect of clothing and shelter, there ignorance, superstition, physical prowess and sexual passion have an equal chance with intelligence, foresight, thought and self-control." There is no superfluous energy for the higher things of life. Thus it has come about that the natives of the tropics have the general reputation of being indolent and untrustworthy; of always being ready to put off until "to-morrow." Obviously, no such sweeping generalization is to be taken too literally, for the lower latitudes have produced men far from deficient in physical and intellectual power, and in those parts of the tropics where natural conditions are more severe, the natives are usually more industrious. But it is true that the energetic and enterprising races of the world have not developed under the easy conditions of life in the tropics. Edward Whymper's Swiss guide said of the natives of Ecuador, "it would be good for tropical peoples to

[1] Based on a lecture given at the Lowell Institute, Boston, Mass., December 6, 1928.

have a winter." Guyot put the case in this way:

> A nature too rich, too prodigal of her gifts, does not compel man to snatch from her his daily bread by his daily toil. A regular climate, the absence of a dormant season, render forethought of little use to him. Nothing invites him to that struggle of intelligence against nature which raises the forces of man to so high a pitch, but which would seem here to be hopeless. Thus he never dreams of resisting this all-powerful physical nature; he is conquered by her; he submits to the yoke, and becomes again the animal man—forgetful of his high moral destination.

"What possible means are there of inducing the inhabitants of the tropics to undertake steady and continuous work, if local conditions are such that from the mere bounty of nature all the ambitions of the people can be gratified without any considerable amount of labor?" In these words, Alleyne Ireland has well summed up the labor problem in the tropics. If the natives are, on the whole, disinclined to work of their own accord, then either slavery, which has long been repugnant to civilized man, or imported labor, becomes inevitable if the tropics are to be developed. With few exceptions, and those where the pressure of a large population necessitates labor, effective development has in the past been accomplished only where imported Chinese, Japanese or coolie labor under some form of contract has been employed. Negro slavery began in the West Indies, under early Spanish rule, and its perpetuation was certainly in part aided by climatic controls. When slavery was abolished, large numbers of planters in English colonies were ruined. In Java, Holland succeeded by obliging the natives to work.

With a large native class which is indolent, working intermittently for low wages, or which is bound under some form of contract, it follows that the native or imported laboring classes are separated by a wide gulf from the upper, employing class, which is usually essentially foreign and white. The latter class tends to become despotic; the former, to become servile. Marked social inequalities thus result, accentuated by the fact that the foreign-born white is usually debarred from hard labor in a hot tropical climate. White laborers are not likely to become dominant in the tropics for two reasons: first, because the climate is against them; and, second, because the native is already there, and his labor is cheaper. White men are not doing the hard daily labor of India or of Java or of the Philippines or even of Hawaii. They are directing it. Except as organizers and overseers, they can not, so far as experience has shown, take part in the hard work of production and development. Physical labor for the great majority of the white race has definite limits. "The climatic environment makes it difficult for the body to keep cool, and as muscular activities increase the heat output, it is inevitable that such exercise should be avoided as much as possible." It has been urged, and not without reason, that white residents in the tropics would do well to follow the natives' example of moving slowly and of being lazy, but obviously habits of listlessness and of postponement till the morrow are not conducive to the exploitation of the tropics, and it is for that purpose that the white race is there.

I myself believe that the future must seek the solution of the problem mainly in the introduction of labor-saving machinery of all kinds, built for and adapted to tropical climates and tropical products and largely run by skilled white mechanics and engineers.

The government of European possessions in the tropics has thus far been determined chiefly by three considertions: First, the general incapacity of the natives, through ignorance or lack of

interest, to govern themselves properly; second, the fact that the white residents are generally comparatively few in number and are only temporarily in the country, to make money and then to go home again; third, the marked class distinction already referred to. These generalizations must obviously not be carried too far. The white residents constitute a caste and naturally become the rulers, the home government retaining general control, often by force of arms. The native population, although largely in the majority, may have little or no voice in its own government. This is clearly not a democracy. It thus comes about that the tropics are governed largely from the temperate zone; the standards and ideals come from another land. And where governed under their own auspices, as independent republics, the success has not as a rule been great. Buckle first strongly emphasized the point that hot countries are conducive to despotism and cold countries to freedom and independence, and the control of climate over the form of government was discussed by the late Lord Bryce in a short but highly significant article in the *Century* for March, 1899. This article attracted very little attention at the time of its publication and seems hardly to have been referred to since then. Yet, at least to my own mind, no more noteworthy consideration has ever been given to this subject, and, coming from Lord Bryce, the opinions there expressed are naturally entitled to great weight. The article deals with "British Experience in the Government of Colonies." There are three types of colonies, distinguished from one another by climate and also by race and form of government. These are named temperate, subtropical and tropical. In temperate colonies the people from the mother-land live and thrive; do outdoor work; bring up strong and healthy children, and do not need a continued immigration of the home stock in order to maintain the race at its prime of physical and mental vigor. In the subtropical colony the colonizing race can not perform steady, hard labor, although it is able to live and maintain itself in health generation after generation. In the tropical colony Europeans, by reason of climatic limitations, can neither do outdoor labor nor keep their bodily and mental vigor. Children born in such climates are usually weak and sickly. Exceptions to this general rule are found in the Hawaiian Islands, "so far favored by their oceanic position," as Lord Bryce put it, "as to be a healthful dwelling-place for Americans and Englishmen; and the same remark applies to parts of the high inland plateau of South Africa, situated north of the tropic of Capricorn."

European races have occupied the temperate colonies, as, *e.g.*, North America, Australia, the cooler parts of South America; the bulk of the people are or will be European and have developed or will develop European institutions and a European type of civilization. The population of the subtropical colonies is chiefly, or largely, non-European. The laboring class, which makes up the bulk of the population, belongs to a lower type of civilization; it is usually native to the soil, although in the case of the Chinese and the Japanese in the Hawaiian Islands, the Indian coolies in Natal, and the Negroes in Cuba, the labor was imported. There are thus two different classes, usually sharply separated. In the typical tropical colonies, among which Lord Bryce placed central Africa, Madagascar, northern and eastern South America, British India, Java, Borneo and the Philippines, the race distinction is even more obvious. The Europeans or Americans are few, while the native or colored population is very large, and,

with certain exceptions, has a low type of civilization. The immigrant white population is relatively small; it is not acclimated; it is not there to stay.

In the temperate colonies the institutions are similar to those at home because the people are used to a civilized administration and to a constitutional form of government, and are capable of carrying them on. Canada and Australia are examples. The problems of government are inevitably very different in subtropical and tropical colonies. Here there is not one homogeneous race, imported from the mother-land, but there are two or more races. The native race, usually colored, is distinctly in the majority, and is in occupation of the agricultural and pastoral land. It is inevitable that the relations of the upper and the lower groups of the population should present many very complex and difficult problems, as, *e.g.*, the adjustment of the social relations. A survey of the history of subtropical colonies in British South Africa and in Algeria, and of tropical colonies in India, the West Indies, Ceylon, Fiji, Tongking, Madagascar, the Congo region and East Africa, led Lord Bryce to the conclusion that "it is . . . possible to have a species of representative self-government in [the] . . . subtropical territories. True, it is not a government by the whole people, *i.e.*, by the inhabitants generally. It is government by the European minority only, yet so far as this European part goes, and when viewed from the side of the mother-country, it is self-government."

In the case of the typical tropical colonies, if they are to have representative government, that government must follow one of two methods. One would give the suffrage to all the natives, or at least to the upper class of natives. The second would restrict the suffrage to the white population. There are obvious objections to either method. Great Britain's experience with both methods, in one form or another, was not encouraging. Other systems of government, tried in various forms, are also considered in Lord Bryce's article. "In all these colonies—and the same remark applies to India—the home methods of self-government have been rejected as unsuitable." A despotic government has been the one which, to quote from Lord Bryce, the English have been "obliged to apply to their tropical colonies" in which the white population is a relatively small, temporary and fluctuating one, with the great mass of the people far too ignorant to carry on any representative form of government. "Only through despotic methods," Lord Bryce wrote, "could have been done for India what the English have done. . . . These things have been achieved by an efficiently organized civil service, inspired by high traditions, kept apart from British party politics, and standing quite outside the prejudices, jealousies and superstitions which sway the native mind."

The question of the government of tropical colonies or protectorates or mandates is one for the future rather than of the past. As Lord Bryce clearly showed, the character of the population determines the form of government, and is itself very largely determined by the climatic limitations on white settlement and acclimatization. The classification of colonies on a climatic basis is fully justified. Such a classification commends itself to the climatologist as logical and simple, and it was suggested by one of the greatest authorities on government. It is, therefore, doubly justified. In looking into the future, one consideration may perhaps eventually have considerable importance, and that is the fact that the Mediterranean peoples on the whole become more readily acclimated in the hot, moist tropics than do those who come from the

higher latitudes. Also, the Latin peoples have far less prejudice against intermarriage with the native.

The very Europeans who exercise the controlling power in the tropics themselves tend to become enervated if they live there long; they lose many of the standards and ideals with which they started; they not uncommonly tend to fall towards the level of the natives rather than to raise the standards of the latter. The peculiar situation which may arise from the government of a tropical possession in which the white race does not become acclimated was emphasized some years ago by Dr. Goldwin Smith in a discussion of British rule in India. "British Empire in India," he said, "is in no danger of being brought to an end by a Russian invasion. It does not seem to be in much danger of being brought to an end by internal rebellion. Yet it must end. Such is the decree of nature. In that climate British children can not be reared. No race can forever hold and rule a land in which it can not rear its children." Or, as a recent English writer has put it:

> The natives, better suited to the conditions (of heat, light, disease, and the like), persist, and under the peace we have brought, multiply at a rate with which our own hampered immigration can not keep pace. Judging by the analogy of all history, our ultimate and certain fate in them is absorption or expulsion. A handful of aliens can not forever control multitudes to whom they teach their own arts. Even over South Africa, where natural conditions are least adverse, hangs the shadow of ultimate native predominance.

It would seem as if the development of agriculture on a large scale in the tropics, in order to provide a future food supply, would be a very simple matter. Here are immense areas with heat, humidity and deep soils; where frost is unknown; where high winds are very infrequent, and where it is always summer. All the conditions seem to be favorable. But the real facts in the problem are very different. Tropical soils are far less fertile and far less available for agriculture than is generally supposed. The warm heavy rains leach out the soil, carrying off many salts valuable as plant foods and leaving the land poor. Hence it becomes a common practice for the tropical farmer in the forest clearings or at the edge of the forest to plant a new patch of ground every year or so. Clearing land in the dense forests of the equatorial belt is very difficult, even almost impossible, owing to the dense growth of vegetation and to the rapidity with which the trees come back onto the cleared spaces. If cleared, the heavy rains wash the soil down the slopes. Weeds grow with almost inconceivable vigor; harvesting is interfered with by the rains; there are innumerable insect pests, blights and rusts; road construction is expensive and difficult; fevers of many kinds and other ailments are a serious handicap; the rains fall in such heavy showers that they are often damaging rather than helpful.

The savannas offer more favorable opportunities for agriculture in the fact that they are open grasslands, and no forests need to be cut down, but their soils are usually poorer than those in the forests, and the dry season, while good for clearing, tilling and harvesting, is often so deficient in rainfall that widespread droughts prevail, crops fail and famine follows. There is no doubt that these savannas will, in time, be more thickly populated and more valuable than now, especially where irrigation can be practiced. Under the supervision of white overseers, the natives will become better agriculturists and cattle-raisers. Some years ago, when, as a member of the Shaler Memorial Expedition, I spent part of a summer on the interior campos of southern Brazil—those vast stretches of grassland and of

scattered tree growth which make up so much of that country—the one question which was borne in upon me every hour of the day was this: What is to be the future of these vast savannas? To-day they are simply examples of colossal waste—waste of space; waste of soil; waste of rainfall; waste of sunshine. Fire devastates them, far and wide. Coarse grass, not eaten by cattle, covers square mile after square mile. Only here and there, as yet, at long intervals, at some lonely hut, was there any attempt to make the soil produce anything except the natural grass; only occasionally did I see a small herd of cattle or horses; only at long distances apart are there towns.

Yet these great campos certainly have a future. Nature has provided a climate better than that of much of the western United States. The high temperatures and abundant rainfall of the summer are followed by glorious bright, warm days and cool nights in the dry winter. There are drawbacks, of course. The dry season, the heavy thunderstorm, the hail, the frost, are to be reckoned with. But where the soil is ploughed and worked, it yields good grass for cattle and horses. Even now, thousands of cattle and horses could be pastured where all is still waste land. Where the attempt has been made, in the towns and around the huts, vegetables are to-day successfully raised. The problem is essentially one of time and labor and intelligent adaptation of crops to the climatic conditions. Cattle and sheep raising, and later farming, will come. Experiment stations must be established at various points. Wheat and cereals of different kinds can surely be found that will do well under the conditions of climate and soil which here exist.

These campos are no more unpromising than was, a few years ago, much of our own western country, where to-day are seen fields of wheat or of corn or of alfalfa. The shriek of the locomotive, not yet heard over great districts which I crossed, has meant the beginning of the development of that country. A farming and cattle-raising population will come in, as it came into our West. What is needed is a large influx of sturdy peasants from the north of Europe, who will not be afraid of hard work; who will intelligently till the soil and care for their crops; who will adjust their crops to their environment.

In the future, with increasing exploitation by the white race and under its control, and with growing demands on the part of the natives themselves, tropical industries are certain to develop. Such development has already taken place to a surprising extent, as in the mills and factories of India, for example. Great industries can be developed in tropical countries, although they are and will be handicapped by the lack of steady and efficient workers. Here, again, the introduction of labor-saving machinery, to replace as many native workers as possible, will solve many of the present problems. Machines do not feel the tropical heat. They do not need to become acclimated. They can be made to work steadily. And they require the supervision of relatively few skilled white machinists and operators. It is an interesting fact that both the United States and European countries have invented and manufactured machines especially intended for harvesting and preparing for export the products of the tropics, such as machines for splitting coconuts; for preparing and extracting oil from the palm; for pulping, hulling and sorting the coffee bean, and so on. The future will witness the use, in large numbers, of cultivators and harvesters made in extra-tropical latitudes, and of industrial machinery of many kinds.

In the future, also, the white man will make life far more comfortable, and safer, in the tropics by building houses better suited to tropical climates; by the wide-spread use of electrical cooling and ventilating devices; by constructing buildings which will, so far as possible, resist the terrific force of the wind in the districts visited by tropical cyclones. Acclimatization of the white race in the tropics can not be accomplished by any of these methods. That individuals from colder climates may live in the tropics, some of them for years, without any serious impairment of health, is true. But the general consensus of expert medical opinion to-day is that, for the white race as a whole, acclimatization is and always will be impossible. By acclimatization is here meant that, by and large, successive generations of white men, even if they are fortunate enough to escape all specific tropical diseases, can not live in the tropics without serious impairment of their physical and mental vigor.

FACILITIES IN BRAZIL, ARGENTINA, CHILE AND PERU FOR BOTANICAL INVESTIGATION AND TRAVEL

By the late Professor JOHN WILLIAM HARSHBERGER

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A COMMITTEE on the preservation of natural conditions of the Ecological Society of America with the assistance of numerous organizations and individuals prepared under the editorship of Victor E. Shelford and Forrest Shreve and a corps of associates and special editors a volume entitled "Naturalists' Guide to the Americas." It was printed at Baltimore in 1926 by the Williams and Wilkins Company. It is illustrated by some sixteen figures, and the areas treated are provided with bibliographies. The volume provides data about all the natural areas and regions of North America, including Central America, Panama and the West Indian islands. The natural history of northern South America is presented in about fifty-eight pages. The following South American states are described with the names of the collaborators: Colombia (Francis W. Pennell), Venezuela (H. Pittier and H. B. Baker), the Guianas (William Beebe and H. A. Gleason), Ecuador (Wilson Popenoe and H. E. Anthony), the Amazon Valley (Orland E. White). It will be noted, therefore, that Peru, Bolivia, Chile, Paraguay, Uruguay, Argentina and all Brazil approximately south of the tenth degree of north latitude have been omitted from consideration in the "Naturalists' Guide to the Americas." The following notes have been assembled with the idea of presenting facts which the writer collected on botanical travel in central and southern Brazil, Argentina, Chile and Peru during the summer of 1927.

Means of Access: The Munson Line and Lamport and Holt Line of steamships furnish passenger service to the east coast of Brazil. The steamers of the Munson Line are comfortable and commodious; they run directly from New York to Rio de Janeiro, and take two weeks to make the passage outside of the Bermuda Islands. Fairly good weather may be expected during the northern summer between New York and Cape San Roque, the easternmost point of Brazil. The same lines can be used on the return trip to New York. If the naturalist elects, he can return from Valparaiso in Chile by the Grace Line steamers, which stop to load freight and passengers at various ports in Chile and Peru, such as Antofagasta, Iquique, Arica (Chile), Mollendo, Callao (Lima), Salaverry, Talara (Peru). The route of the Grace Line steamers is through the Panama Canal, with stops at Balboa (Pacific side) and Cristobal (Atlantic side). It takes three weeks to make the trip from Valparaiso to New York. The Munson Line and Grace Line are operated by Americans, while the Lamport and Holt Line is English.

Hotel Accommodations: Modern hotels equal to the best in the larger cities of the United States are found in Rio de Janeiro, São Paulo, Buenos Aires and Valparaiso. The rooms, the service and the cuisine are excellent. If the naturalist takes one of the larger cities as his center of operations he will find hotels less high priced than the best with fairly good accommodations, as he can at home by choosing the less expensive hostelries. In such inland towns as Campos do Jordão, Santa Maria and Uruguayana, Brazil, the hotels are fair. One excep-

AN ANT-INHABITED TREE, *CECROPIA ADENOPUS*
IN MOUNTAINS BACK OF RIO DE JANEIRO, BRAZIL, AND ABOVE PAINEIRAS, JULY 18, 1927.

INTERIOR VIEW OF TROPICAL RAIN FOREST
ABOVE TIJUCA, RIO DE JANEIRO, BRAZIL, JULY 20, 1927.

SAND DUNES

ALONG COAST ENVIRONS OF RIO DE JANEIRO, BRAZIL, WITH TERRESTRIAL BROMELIAD, *Aechmea nudicaulis*, JULY 16, 1927.

tion was found at Mendoza in western Argentina where an exceptionally good hotel was found, the Hotel Plaza.

Vegetation Worthy of Study: The mountains behind Rio de Janeiro within easy access of the city by electric trolley lines, by autobus and by railroad are covered from bottom to top with a tropical forest. If the time of the botanist is limited, the tropical rain forest may be reached by ascending the Corcovado, (710 meters, 2,329 feet) from which a magnificent view of the city, the ocean and the country is to be had. A good trail leads down to Paineiras, where there is a hotel and restaurant, or farther down the mountain to Silvestre. This trail leads directly through the tropical rain forest and is advantageous for taking photographs or noting the general character of the vegetation, which would not be possible if one had to force his way through the dense growth. From Silvestre, the Estrada da Lagoinha can be followed to Sumare and then down into the city, or Rua de Aqueducto can be used down through Bella Vista into the Santo Antonio section of Rio de Janeiro. Another excursion can be made to the waterfalls and the rain forest of Tijuca. The restinga, or coastal thicket association with nearby dunes, can be investigated beyond Copacabana at Ifanema, where fresh-water marshes and granite cliffs harbor interesting rock algae, lichens, mosses and flowering plants (*Tillandsia aranjei*, etc.). The color of the granite cliffs, due probably to the growth of blue-green algae, suggests the Piedras Negras in Angola, Africa, the black color of the rocks there being due to algal incrustations.

Proceeding south from Rio de Janeiro by the Central Railroad of Brazil to Rezende Station, a side trip can be made to Bocaina, where the Sierra Bocaina can be ascended. Here *Araucaria brasiliana* begins to make its appearance on the mountains. Beyond Rezende Station is Homem del Mello, from which place the ascent of Itatiaia is possible and the botanist can acquaint himself with the vegetation of the highest peak of the Sierra Mantiqueira so ably described by Dusen. At Pindamonhangaba an electric train will take the visiting scientist to Campos do Jordão. Campos do Jordão is 1,573.80 meters (4,952 feet) in altitude and is distant from Pindamonhangaba about forty-seven kilometers.

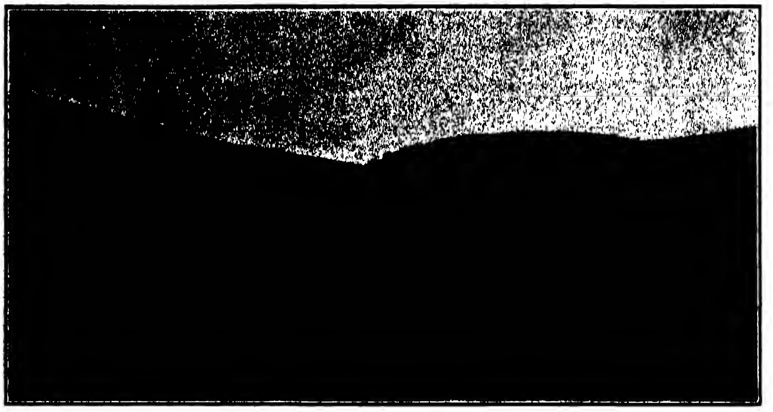
Here is an excellent place to investigate the vegetation of the rolling savannas, or campos, and the groves of *Araucaria brasiliana,* but the botanist should be careful about the hotel at which he stops, for Campos do Jordão is a resort for Brazilians with tuberculosis and inadvertently the disease might be contracted. A preliminary cross section of the vegetation between Pindamonhangaba and Campos do Jordão revealed cleared and cultivated land, river marshes and swamps, savannas, savanna forests (*cerradão*), second growth timber (*caapueira*), rolling campos with scattered palms and trees, rain forest up to 1,500 meters (4,500 feet), upland campos from the upper limit of the rain forest to 5,600 feet alternating with groves of *Araucaria brasiliana.*

São Paulo in the heart of the coffee district has some interesting fresh-water marshes (fenland) near its outer limits. It is feasible to visit Alto da Serra and the biological station there, for the rich tropical rain forest can be penetrated by means of trails which have been constructed to facilitate the study of the vegetable life consisting of palms, tree ferns, orchids, bromeliads, filmy ferns and lianes.

The rolling campos country extends into the Brazilian State of Parana. On July 28, 1927, a white frost covered the campos, where herds of cattle were feeding. Araucaria forests alternate with the open country, and as one proceeds southward by rail to Vallinhas and Teixeira Soares, the valleys and hill slopes are covered with pure stands of Parana pine (*Araucaria brasiliana*). Saw-mills are found at a number of stations as at Fernandes Pinheiro where the araucarian logs are piled high preparatory to being sawed. Iraty would be a good place to stop on the main railroad line to study the Parana pine forests, for there are two small hotels here, the Hotel Estrella and the Central Hotel, where the botanist might stay while investigating the forest vegetation.

The summer-green forest of deciduous and evergreen broad-leaved trees is characteristic of the State of St. Catharina

LARGE *ARAUCARIA BRASILIANA*, CAMPOS DO JORDÃO
AT 5,000 FEET ELEVATION, BRAZIL, JULY 23, 1927.



HILLY CAMPOS ABOVE 5,000 FEET

CAMPOS DO JORDÃO, BRAZIL, JULY 23, 1927. NOTE GROVES OF *Araucaria brasiliana* AND *Podocarpus Lamberti* IN THE DEPRESSIONS BETWEEN THE ROUNDED HILLS.

around Pinheiro Preto. Bamboos occur in the forest, a tall flexuous Cocos and bromeliaceous epiphytes, although on the tops of the ridges *Araucaria brasiliana* is seen occasionally. The southern limit of *Araucaria* in this direction seems to be at Herval before crossing the Uruguay River into the State of Rio Grande do Sul at Marcellino Ramos. At Pulada, the boundless prairie plain, or pampas, is entered and this plain is broken by groves or longitudinal forests of *Araucaria*, which occupy the depressions. This type of vegetation can be studied by a stop at Carasinho, where there is a small hotel (Hotel Familiar), or at São Bento the Hotel Rio Grandense. The size of the campos forest groves here is indicated by the number of *Araucaria* trees found in them. Porongas is the absolute southern limit of the *Araucaria*. South of Cruz Alta herds of rhea, or South American ostriches, are encountered on entering upon the limitless pampas. Santa Maria is an important inland city, and Uruguayana in southwestern Brazil is on the Argentine frontier on the Uruguay River.

The ride on the railroad from Libres to Buenos Aires is comparatively uninteresting until the Parana River is reached with its extensive river marshes (fenland). Here the tall clumps of pampas grass (*Gynerium argenteum*) with waving plumes are at their best. The trains are carried across the fen country on large ferry-boats with a good opportunity to see the marsh vegetation. Many of the marsh islands have been planted to poplars and willows, which have grown up to form the alamos. The trees furnish firewood in a country naturally destitute of forest.

Buenos Aires can be used as a center for the investigation of the vegetation of the pampas. The writer was in Buenos Aires during the latter part of the southern winter, and on a visit to La Plata he stopped at Conchitas where the pampas seemed least disturbed. Here the pestiferous character of the cardoon (*Cynara Cardunculus*) was noted as this weed encroaches on the natural pampean vegetation. The Italian settlers must exercise constant vigilance to keep it in subjection. In crossing the pampas of Argentina from Buenos Aires to Mendoza, a gradual imperceptible ascent is made to the eastern foothills of the Andes, across a plain tilted in an east-west direction. The eastern part of this plain has been set-

tled, but the western part before reaching the vine-growing districts about Mendoza remains wild, open country with flocks of rhea encountered as one proceeds.

After leaving Mendoza by the Transandine Railroad the country becomes more rolling and more deeply dissected, resembling the western plains or the steppes of the eastern foothills of the Rocky Mountains in its topographic configuration. The vegetation, however, resembles the desert plains or mesas of the Colorado and Mohave deserts owing to the presence of a desert shrub *Covillea (Larrea) divaricata*, related generically to *Covillea tridentata* var. *glutinosa* of the northern plains. An interesting phytogeographical problem is presented in the distribution of the species of *Covillea* and other associated plants in North and South America separated by tropical vegetation. Mendoza might be made the center for such botanical investigation.

Reaching the western slopes of the Andes, the distribution of plants on Mount Aconcagua, the highest mountain in North and South America, might be studied, especially the altitudinal arrangement of the plants of the several belts. The presence of many species of the subantarctic forest on the Pacific slopes of the Andes along the Transandine Railroad would yield a rich botanical harvest. Santiago, Valparaiso and Puerto Montt might be used as centers for the study in detail of the vegetation of southern Chile. All these places are connected by railroad. With a seaworthy launch the channels and archipelago of islands as far south as the Strait of Magellan can be reached from Puerto Montt, as also the subantarctic forests where *Araucaria imbricata* and species of *Nothofagus* occur. Las Zorras, reached by electric car from Valparaiso, and Torpederas on the west coast are accessible to the botanist and should be visited during the spring and the summer of the southern hemisphere. A newly opened railroad to Lake Nahuelhuapi on the border between Patagonia and Chile will enable the botanist to

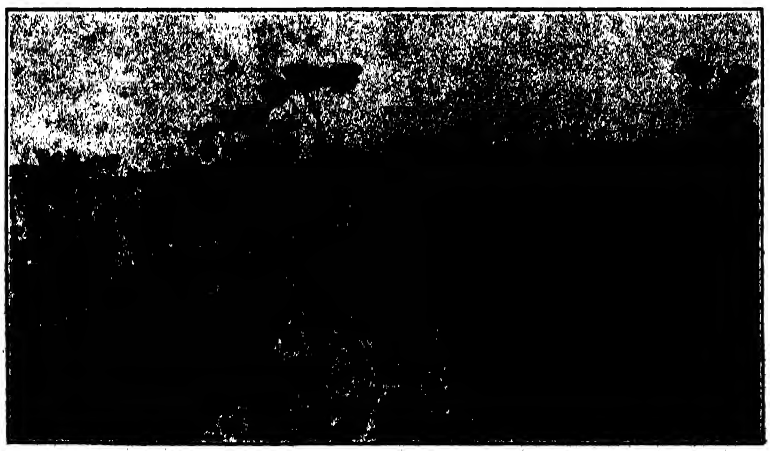
TERRESTRIAL BROMELIADS

IN TROPICAL RAIN FOREST AT ALTO DA SERRA, BRAZIL, JULY 26, 1927.

SHRUBBY LOBELIA, *LOBELIA SALICIFOLIA*
CHAPPARAL AT LAS ZORRAS, VALPARAISO, CHILE, AUGUST 15, 1927.

reach some of the least-explored parts of the subantarctic forests and also the Andes south of the 40th parallel of south latitude.

Botanical Gardens and Scientific Institutions.—The large and interesting botanical garden (Jardim Botanico) in Rio de Janeiro is reached easily by electric car from the heart of the city. It has a magnificent situation in a depression between two mountains covered with tropical rain forest. The forested slopes come down to the upper edge of the botanical garden, so that the planted grounds and the virgin forest are in juxtaposition. The Brazilian government should include the forested mountain slopes from base to summit with the Jardim Botanico and construct trails through the virgin forest, so that the wild vegetation would be preserved and would be open for study to visitors and scientists interested in the life of tropical regions. There would then be cre-



PAMPAS AT CONCHITAS, ARGENTINA
COVERED WITH INTRODUCED, WEEDY CARDOON, *Cynara cardunculus*, AUGUST 9, 1927.

ated a wild botanical garden and a cultivated one. In the Jardim Botanico there is a laboratory and museum building at one side of the garden where the botanical specimens are housed and a herbarium.

The Museum Nacional, which occupies the old imperial palace, is located in a large park planted with many interesting tropical trees. Several rooms are devoted to botany. Sala Freire Allemão contains a collection of the trunks, samples of rubber, fruits and mounted herbarium specimens with three oil paintings by Santos on the walls representing Amazonia, or Hylaea, Campos and Araucaria forest. Sala Martius Botanico is devoted to herbarium specimens arranged in cases according to natural families, to pictures of vegetation, to wood samples, to alcoholic fruits and to phytogeographic maps. There are oil paintings of Martius, Jacques Huber, Barbosa Rodrigues, Nicolão Moreira, and models of flowers by D'Émile Deyrolles, of Paris. Sala Conceição Vellozo has alcoholic specimens, paintings of water lilies, jack fruit and Victoria regia. The private gardens of the wealthy Brazilians and the city parks also present opportunities for the investigation of exotic cultivated plants.

Escola Superior de Agricultura e Veterinaria de Estado Minas Geraes at Viçosa is presided over by an American scientist, P. H. Rolfs, formerly of the Florida Agricultural Experiment Station. It is a center for the scientific study of agriculture and horticulture. The "priest's room" has been set aside for visiting botanists.

JARDIM BOTANICO, RIO DE JANEIRO, BRAZIL

WITH THE CORCOVADO IN THE BACKGROUND, PALMS ON HILL SLOPES AND SHRUBS OF *Azalea* (*Rhododendron*) *indica* IN THE FOREGROUND, JULY 15, 1927.

Estacão Biologica do Alto da Serra is situated on a hillside in the midst of a dense tropical forest. Here is a building used in part as residence for the caretaker and in part as a laboratory. The botanical garden, coincident with the tropical rain forest through which broad foot trails have been constructed, is thus accessible in all of its parts. The sta-

GROUP OF PALMS IN BOTANICAL GARDEN

AT BUENOS AIRES, ARGENTINA, AUGUST 5, 1927. THE LOW PALMS IN FRONT OF THE GROUP ARE *Washingtonia filifera* AND *Chamaerops humilis*. THE TALL PALMS ARE *Phoenix canariensis*.

JARDIN BOTANICO, LIMA, PERU

LARGE FIG TREE, *Ficus sp.*, WITH ROPE-LIKE, HANGING AERIAL ROOTS, AUGUST 24, 1927.

tion is controlled by the Chefe da Seccão de Botanica de Museu Paulista and as the official publication appears Archivas de Botanica de Estado de S. Paulo. In this forest are tree ferns, epiphytic bromeliads and orchids, tall forest trees draped with lianes and filmy ferns.

Museu Paulista in the environs of São Paulo has a room in which botanical and herbarium specimens are displayed and in the City of São Paulo is located the herbarium and botanical library on the second floor of No. 31 Rua Conselação, over an agency for Ford automobiles. Dr. F. C. Hoehne is the able director in charge. There is a botanical garden (Horto "Oswaldo Cruz") associated with the Instituto Butantan. One section of the grounds is devoted to a snake farm, where poisonous reptiles are kept to secure their venom for remedial and experimental purposes. Butantan is one of the suburbs of São Paulo.

The Jardin Botanico in Buenos Aires is richly stocked with plants arranged in systematic beds. One section of the garden consists of a geographical arrangement. Here one finds segregated Argentinian, Brazilian, Chilean, Australian, Uruguayan, European, North American, African, Asian and Japanese plants. Unusual opportunity is given for the study of trees of northern climes growing in the southern hemisphere.

The public gardens adjoining the botanical and zoological gardens are well worth a visit. La Plata is reached by Ferrocarril del Sud. The celebrated museum is reached best by taxicab from the railroad station. A small room is devoted to the botanical collections.

The botanical garden at Santiago, Chile, is a fine one. Although Valparaiso does not have a botanical garden, it has in Jardin Suizo, owned by Benjamin Pümpin and his son Enrique, at Las Zorras, a large collection of exotic and native species grown for ornament and for sale. The catalogue of the Jardin Suizo is useful as an indication of the exotic and native plants which can be grown in southern Chile.

The City of Lima, Peru, boasts a school of pharmacy connected with its university. The building of the school of pharmacy is located in the Botanical Garden, which has a large and representative collection of plants of temperate and tropical regions and is a center of botanical influence on the Pacific coast of South America.

Altogether a survey of the facilities for botanic investigation and travel in Brazil, Argentina, Chile and Peru indicates that the botanist will find much of interest in the botanical gardens and institutes maintained for the scientific study of plants, but above all the comforts of home need not be sacrificed by a prolonged stay in order to investigate the native flora and the vegetation, which present many features of absorbing interest.

HYPNOTISM IN SCIENTIFIC PERSPECTIVE

By Professor CLARK L. HULL

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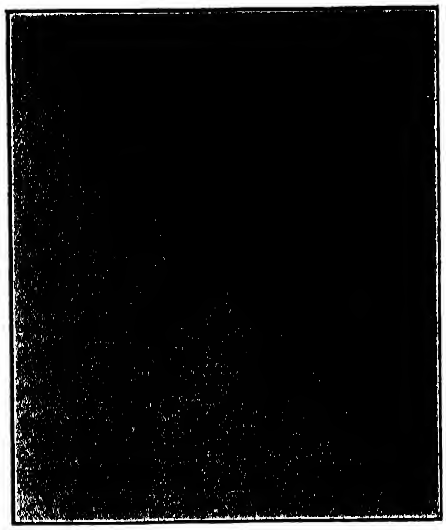
PHENOMENA more or less resembling those of the hypnotic trance appear to have been known from very early times, especially among oriental peoples. For the most part, these states were associated with religious and mystical practices. While of interest to the curious, this phase of the history of hypnosis has left no tangible contribution to science. It is sufficient to observe that hypnotism originated in magic just as chemistry arose from alchemy and astronomy from astrology.

About the time of the American Revolution Franz Anton Mesmer (1733–1815), a Viennese physician, put forward to the scientific world the theory and practice of what he called animal magnetism. Mesmer's medical training naturally made his interests clinical. No doubt the spirit of the times tended to tinge his practice with something of the mystical. In any case, having failed of success in Germany, he went to Paris in 1778 where he soon had a tremendous vogue. There he opened a remarkable clinic in which he treated all kinds of diseases.

The clinic was held in a large hall which was darkened by covering the windows. In the center of this room was a large oaken tub, the famous *baquet*. The tub was filled with water into which had been placed a quantity of iron filings and ground glass. Over the tub was a wooden cover provided with openings through which projected jointed iron rods. These rods were applied by the patients themselves to their various ailing parts. While at the tub, the subjects were commanded to maintain absolute silence, possibly to render them more susceptible to the plaintive music that was provided. At the psychological moment, Mesmer would appear on the scene garbed in a brilliant silk robe. He would pass among the patients, fixing his eyes upon them, passing his hands over their bodies and touching them with a long iron wand. Individuals apparently suffering from the most varied disorders declared themselves cured after two or three such treatments.

Mesmer did not hypnotize his subjects, although some of them appear to have had spontaneous hysterical convulsions and to have shown other related behavior while at the tub. The sleeping trance which is a familiar part of hypnotism today seems to have been discovered accidentally in 1784 by a follower of Mesmer, the Marquis de Puységur. One day he attempted to apply Mesmer's magnetizing methods to Victor, a young shepherd, who, instead of showing the usual hysterical convulsions, fell into a quiet sleeping trance. Without awaking, he later went about his duties like a sleep-walker. When he finally awoke from his somnambulistic state, he was unable to recall anything that had happened while in it. Victor's inability to recall the trance events would now be called post-hypnotic amnesia. The sleeping or trance condition was quite naturally regarded as an artificially induced somnambulism and at once it attracted a great deal of attention, partly on account of the supposed clairvoyant powers of subjects while in this state. About the same time Pététin, a physician at Lyons, described the phenomenon of hypnotic catalepsy or muscular immobility. The discovery of the remaining major hypnotic phenomena followed rapidly, and by 1825 hypnotically induced positive hallucinations (seeing



F. A. MESMER (1733–1815)

things which are not present), negative hallucinations (being blind to things really present), hypnotic anesthesias, analgesias (insensibility to pain), and the action of post-hypnotic suggestion had all been clearly described.

The theories of animal magnetism as put forward by Mesmer and as elaborated by his followers are of considerable scientific interest, not because they were true, but because, on the contrary, it took the world such a long time to realize that they were false. In 1766 Mesmer wrote his medical dissertation on the influence of the planets upon the bodies of men. This survival of the traditions of astrology he combined with the theory that the two lateral halves of the human body act like the poles of a kind of animal magnet. Disease was caused when there was an improper distribution of this magnetism within the body. Animal magnetism itself was held to be a kind of impalpable gas or fluid, as distinguished from the magnetism of minerals. The distribution and action of animal magnetism were supposed to be under control of the human will. Mesmer's followers even thought that this strange fluid could be seen. Trained somnambulists were supposed to behold it streaming forth from the eyes and hands of the magnetizer, though they disagreed as to whether the color of the strange fluid was white, red, yellow or blue. It was agreed, however, that the fluid could be confined in a bottle and thus transported, exerting its mystical power in distant places!

The century which has elapsed since 1825 has been much less fertile in the discovery of hypnotic phenomena than the preceding half century. Indeed almost the only outstanding events during this period have been the gradual though still incomplete correction of errors which accumulated around the pseudoscience of hypnotism previous to that date. One of these is its approximate escape from its age-long entanglements with mysticism and magic. A second and more dramatic episode is the struggle centering around the rivalry between the objective theories of animal magnetism and the subjective theory of suggestion as alternative explanations of hypnotic phenomena. It is with events of this latter conflict that we shall now concern ourselves.

The subjective or psychological nature of hypnotic phenomena seems independently to have been discovered and

published by James Braid in England (1843) and by a group of French investigators beginning with the Abbé Faria (1819) and culminating with Liébeault (1866) and Bernheim (1886). In contrast with the French movement, Braid's stroke of insight appears to have been a relatively independent and isolated event. In 1841 he witnessed a mesmeric séance conducted by a French magnetizer named LaFontaine. Braid first went to the demonstration suspecting fraud. Upon witnessing it a second time, however, and after making certain tests of the subjects himself, he became convinced that the phenomena were genuine. He later began experimenting extensively on his own account. This very soon led him to the view that the cause of the various phenomena was not a fluid which passed from the body of the mesmerist into that of the subject, but that in reality it all depended upon the suggestibility of the subject himself. Braid is, likewise, notable for having developed a special technique for inducing the trance, a method still extensively used. His procedure was to have the subject look fixedly at some bright object which was held near and slightly above the eyes in such a way that the eye muscles were under a certain amount of strain. This technique was usually combined with verbal suggestion. Braid utilized the trance mainly in his painless surgical operations, which he performed in large numbers. He also introduced the word "hypnotism" now in general use.

The parallel movement in France was much more complicated. It began in 1814–18 when the Abbé Faria showed by experiments, which were later published, that no special force was necessary for the production of the mesmeric phenomena such as the trance, but that the determining cause lay within the subject himself. One of Faria's subjects was a general named Noizet, who was converted to the Abbé's views. He, in turn, passed Faria's teachings on to a physician, Alexander Bertrand, who elaborated them. Both Noizet and Bertrand wrote books upon the subject.

Basing his opinion largely on the striking similarities between the systems of Noizet and Bertrand on the one hand and that of Liébeault on the other, Pierre Janet has advanced the view that Noizet's book may have fallen into the hands of Liébeault. In contrast to this Bramwell calls attention to the fact that Braid's anti-magnetic views were being exploited in France through the influence of Azam and others in 1859–60. In any case, we find Liébeault seriously beginning the study of mesmerism in 1860, but entirely rejecting the theory of a magnetic fluid.

Liébeault was a humble physician who began a country practice in 1850. In 1864 he settled at Nancy and practiced hypnotism among the poor peasants who came to his clinic. The temper of the man is shown by the fact that he accepted no fees for these services, living on his income. Bramwell, who visited Liébeault's clinic, draws such an inimitable picture of it that it must be quoted:

> His clinique, invariably thronged, was held in two rooms in the corner of his garden. . . . The patients told to go to sleep apparently fell at once into a quiet slumber, then received their dose of curative suggestions, and when told to awake, either walked quietly away or sat for a little to chat with their friends, the whole process rarely lasting longer than ten minutes. . . . No drugs were given, and Liébeault took special pains to explain to his patients that he neither exercised nor possessed any mysterious powers, and that all he did was simple and capable of scientific explanation. . . . A little girl, about five years old, dressed shabbily, but evidently in her best, with a crown of paper laurel leaves on her head and carrying a little book in her hand, toddled into the sanctum, fearlessly interrupted the doctor in the midst of his work by pulling his coat, and said, "You promised me a penny if I got a prize." This, accompanied by kindly words, was smilingly given, incitement to work having been evoked

in a pleasing, if not scientific way. Two little girls, about six or seven years of age, no doubt brought in the first instance by friends, walked in and sat down on a sofa behind the doctor. He, stopping for a moment in his work, made a pass in the direction of one of them, and said, "Sleep, my little kitten," repeated the same for the other, and in an instant they were both asleep. He rapidly gave them their dose of suggestion and then evidently forgot all about them. In about twenty minutes one awoke and, wishing to go, essayed by shaking and pulling to awaken her companion—her amused expression of face, when she failed to do so, being very comic. In about five minutes more the second one awoke, and, hand in hand, they trotted laughingly away.

After coming to Nancy, Liébeault began writing a book on hypnotism which was finished after two years of hard work. When published, however, only one copy was sold! But Liébeault patiently pursued his gratuitous labors among the poor for twenty years when, by a kind of accident, his remarkable work was finally recognized. It seems that Bernheim, a professor in the medical school at Nancy, treated without success for six months a case of sciatica which had lasted for six years. This patient was quickly cured through hypnotic suggestion administered by Lié-

A. A. LIÉBEAULT

JAMES BRAID (1795–1860)

beault. This striking cure caused Bernheim to investigate the novel method of treatment. His initial incredulity soon changed to enthusiastic admiration, and in 1884–6 Bernheim published an attractively written book in which he directed the attention of the world to Liébeault's work. In this tardy way, twenty years after it had been written, the remaining copies of Liébeault's book were finally sold, and the modest physician at last received recognition. Doctors from all countries now flocked to Nancy to study his methods.

But suggestion as an explanation of hypnotic phenomena was yet to encounter a severe struggle. Independent of Liébeault, Charcot, an anatomist and neurologist of Paris, had, around 1880, attracted considerable attention by his courageous experiments and lectures on the subject of hypnosis. Warned by the unscientific extravagances which had very properly brought the magnetizers into disrepute, Charcot resolved that his experiments, at least, should be ultra-scientific and technically above reproach. It is largely because of this that the controversy which eventually grew up between the Paris and Nancy schools

merits our attention. For, despite Charcot's scientific intentions, no one has ever fallen into more grievous experimental errors or gone more widely astray in experimental method than he. This simply goes to show how easy it is, even with the very best of scientific ideals, to go hopelessly wrong in hypnotic experimentation.

Charcot seems to have been especially fearful of being deceived by his subjects. He therefore sought in their behavior for signs which could not be simulated. Apparently he never hypnotized any one himself but depended upon his assistants who brought the subjects to him. These were mainly three hysterical young women. With these mentally pathological subjects, he sought diligently for objective signs characteristic of the hypnotic state. Quite naturally he employed the same general methods that he had recently applied with success to the study of locomotor ataxia and lateral sclerosis. When the subjects were stimulated, their muscles seemed to show characteristic reactions following definite laws.

All of these phenomena could be successfully linked to Charcot's earlier studies. They could be examined with the guidance of the same anatomical ideas. The same method and the same instruments could be used. The same little hammer could be used for testing the reflexes. As of old, demonstrations could be made by the chief to an admiring circle of pupils. It was still possible to seek upon the bared limb of the subject a place where a blow with the hammer would readily induce a well-marked contracture, and one plainly visible to all beholders. To Charcot this was irresistible. He declared that the study of such phenomena could be conducted by a perfectly sound method; that the method sufficed to exclude the possibility of fraud, which had invalidated the old experiments upon somnambulists; and that it was in the light of the data acquired by this method that a critical review of all the recorded phenomena of animal magnetism must be undertaken.[1]

Pursuing his methods just described Charcot reported a number of supposed discoveries. Major hypnotism, as it was now called, showed three sharply marked stages: lethargy, catalepsy and somnambulism. In the lethargic stage, induced by closing the subject's eyes, the subject could hear nothing and could not speak; but, when certain nerves were pressed, remarkable and uniform contractures resulted. If, while in the lethargic state, the subject's eyes were opened, she at once passed into the cataleptic stage, in which the limbs remained in any position they were placed by the experimenter, though she was still unable to hear or speak. Lastly, if friction were applied to the top of the head, the subject passed into the somnambulistic condition which was substantially that of the ordinary trance. Sometimes these contractures, catalepsies and other hypnotic manifestations appeared only on one side of the body. In such cases, if a large magnet were brought close to the limbs in question, the particular symptoms would be displaced at once to the other side of the body. This phenomenon was called *transference*. Thus, curiously enough, we find magnetism reappearing in the history of hypnotism, this time in respectable scientific garb, though quite as fallacious as when similar claims had been advanced by the old magnetizers.

To these claims of Charcot and his followers, Bernheim replied in the second edition of his book:

If, in our researches, we failed to take as our starting-point the three phases of hysterical hypnotism described by Charcot, this was because we were unable by our observations to confirm their existence. We were unable to ascertain that the action of opening or closing the subject's eyes, or friction of the vertex, modified the phenomena in any way; or that in the subjects who were not disposed to manifest certain phenomena under the sole influence of suggestion, such phenomena could be induced by any of the physical stimuli just mentioned. . . . Conversely, all the phenomena can be readily obtained when they are described in the subject's presence, and when the idea of them is allowed to permeate his mind. Not only can all the classical effects of the magnet be induced

[1] Pierre Janet, "Psychological Healing," vol. 1, p. 168.

in this way, but the same thing applies to all the varieties of transference. I say, "I am going to move the magnet, and when I do so there will be a transference from the arm to the leg." A minute later, the arm falls and the leg rises. Without saying any more to the subject, I next move the magnet back to the leg; thereupon there is a fresh transference from the leg to the arm. *If, without disclosing the fact to the subject, I substitute for the magnet a knife, a pencil, a bottle, a piece of paper, or nothing at all*—still the phenomena are witnessed.[2]

The salutary manner in which Bernheim thus exposed by means of the control experiment the basic error in the experimental technique of the Paris school should be pondered long and well by all who essay experimentation in the field of hypnosis.

The conflict with Paris having been won, there was yet another chapter in the history of hypnosis and suggestion to be written in Nancy. In 1885 the good Liébeault met at Troyes a young druggist named Émile Coué. The two men at once found much in common. For a time Coué studied and practiced hypnotic suggestion according to

EMILE COUÉ

[2] Quoted by Janet, "Psychological Healing," vol. 1, p. 182. Italics ours.

J. M. CHARCOT (1825–1893)

Liébeault's technique. Meanwhile he observed the influence of waking suggestion in effecting cures when associated with the use of drugs, the latter often quite innocuous in themselves.

He studied and brooded over the matter for a period of twenty-five years. In 1910, at the age of fifty-three, Coué established what has sometimes been called the "neo-Nancy" school. Following the example of his predecessor, Dr. Liébeault, Coué held his clinique in his own home and gave gratuitously his healing suggestions to the many who flocked to receive them. But his technique was different. Coué abandoned the trance entirely and depended wholly upon waking suggestion. This he called *auto-suggestion,* insisting that all suggestion is in reality nothing but auto-suggestion.

What Coué meant by the term, auto-suggestion, may best be understood from his quaint directions to a person suffering from pain:

Therefore every time you have a pain, physical or otherwise, you will go quietly to your room . . . sit down and shut your eyes, pass your hand lightly across your forehead if it is mental distress, or upon the part that hurts, if it is pain in any part of the body, and repeat the words: "It is going, it is going," etc. Very rapidly, even at the risk of gabbling, it is of no importance. The essential idea is to say:

"It is going, it is going," so quickly, that it is impossible for a thought of contrary nature to force itself between the words. We thus actually think it is going, and as all ideas that we fix upon the mind become a reality to us, the pain, physical or mental, vanishes. And should the pain return repeat the process 10, 20, 50, 100, 200 times if necessary, for it is better to pass the entire day saying: "It is going!" than to suffer pain and complain about it.[3]

Such, in brief, is the history of hypnotism. All sciences alike have descended from magic and superstition, but none has been so slow as hypnosis in shaking off the evil associations of its origin. None has been so slow in taking on a truly experimental and genuinely scientific character. Practically all of the actual phenomena were discovered and described during the first fifty years, from 1775 to 1825. But the century since 1825 has shown a remarkable sterility in this field. Almost nothing of significance has been accomplished during this period except the very gradual correction of errors which originally flowed directly from bad experimental procedures. We have already had occasion to note a classical case of this in the controversy between Bernheim and Charcot. The tardy development of the science of hypnotism, moreover, is especially striking when it is recalled that practically from the beginning hypnosis has been definitely an experimental phenomenon. Not only this, but experimentation in it has been continuous and widespread through all of this period during which science in other fields has made the greatest advances ever known.

The paradox in this case, as always, disappears with full knowledge of the attendant circumstances. In the first place, as we have already seen, the dominant motive throughout the entire history of hypnotism has been clinical, that of curing human ills. A worse method for the establishment of scientific principles among highly elusive phenomena could hardly have been devised. As we shall have occasion to observe frequently, one indispensable principle of satisfactory hypnotic investigation is that of the control experiment. Thus Charcot's magnetic experiment was utterly misleading and scientifically pernicious until Bernheim completed it by substituting for the magnet "a knife, a pencil, a bottle, a piece of paper, or nothing at all." But deliberately to run a control experiment in genuine clinical practice involves withholding from a considerable number of patients (the control group) a mode of treatment possessing a certain presumption of curative value. This deliberate withholding of the means of life and health from certain individuals, even though on the long run it might greatly profit other individuals, is revolting to ordinary human nature. And, when individual patients are paying individual doctors for treatment, it is quite out of the question. The physician's task is to effect a cure in the quickest manner possible, using any and all means at his disposal more or less simultaneously. Naturally general laws which call for the varying of a single factor at a time do not readily emerge from such situations. Worse still (despite notable exceptions as in the case of Bernheim) the limitations of clinical practice often operate in the behavior of experimenters accustomed to them, even when the conditions surrounding the particular experimental situations are such as really to permit control experiments to be carried out.

What we have spoken of above as the control experiment has long been known and employed by scientific investigators. It is an integral part of the most potent of all scientific methods. This has been known since the time of John Stuart Mill as the "method of difference." According to Mill, it is "by the method of difference alone that we can ever, in

[3] "Suggestion and Auto-suggestion," Coué, p. 82.

the way of direct experience, arrive with certainty at causes." At bottom the method is very simple. Its procedure falls naturally into two parts. The first part is usually thought of as the main or basic experiment. The second part is what we have called the control experiment. It is the almost universal failure of the experimenters to perform part two as required by the method of difference that has proven so disastrous in the history of hypnotism.

In the main or basic experiment by the method of difference there is set up an experimental situation containing a factor *A* which is presumed to be causally active, along with attendant factors *B*, *C* and *D*, all of which are presumed in this particular situation to be non-active. What follows from the joining of these factors is then noted. The result *X*, whatever it chances to be, is likely by the unsophisticated to be taken forthwith as the effect of the antecedent *A*. Thus when Charcot brought the magnet (*A*) close to the contracted leg of the hypnotized subject and the contraction thereupon was transferred to the arm (*X*), he naïvely concluded that the specific magnetic property of the magnet was the active agent. As a matter of fact, no general conclusion whatever as to causation may safely be drawn at this stage of the experiment. It is always possible that the observed consequent *X* may have been caused by the supposedly neutral attendant circumstances *B*, *C* or *D*, or some combination of them, and not by *A* at all.

The second or control part of the method of difference comes in at this point to clear up the experimental ambiguity. In this part a new experiment is set up which is in all respects exactly like the first except that antecedent factor *A* shall be absent. If, now, the consequent *X* is also found to be absent, then the conclusion may be drawn that *A* is in truth the cause of *X*. But if, on the other hand, *X* should really be found among the consequents, it will be quite as clear that *A* is *not* the cause of *X*. This last is what happened when Bernheim carried out the control to Charcot's experiment. With everything else the same, a bottle or a pencil, or only the actions of the experimenter were quite as efficacious in changing contractures as was a true magnet.

No doubt an important factor contributing to the almost universal failure to perform satisfactory control experiments in the history of hypnotism has been the grossly inadequate training of the investigators. Up almost to the present moment their training, if any, has been in the non-mental sciences of physics, chemistry, physiology or anatomy. Almost without exception they have known little or nothing of the technique and peculiar pitfalls of psychological experimentation. The ordinary physicist, chemist or physiologist in his scientific training never encounters the phenomenon of substitution of stimulus (or cause) which takes place constantly in habit formation. Thus it seems never to have occurred to Charcot that a magnet could be causally active in determining human behavior except through its specifically magnetic properties. He did not realize the possibility that through maladroitness in the conduct of his investigations his subjects, even unknown to themselves, might acquire certain habits; that by virtue of these habits the stimulation of their sense organs by a magnet or merely by movements or sounds associated with the use of a magnet might alone evoke the observed reactions. The causal effects in this latter case were, of course, quite as physical as the action of a magnet on iron filings, though the mechanism involved was radically different from what Charcot implicitly assumed.

Despite the very devious and unscientific history of hypnotism, there is ex-

cellent reason to expect a decided change for the better in the near future. The excessive preoccupation with the clinical and other practical applications of hypnotism so characteristic of its history has now subsided to moderate proportions. This can hardly be regarded as anything but a fortunate circumstance for the development of hypnotism as a true experimental science and ultimately for its most effective application as well. Moreover, the rapid development of psychology as an experimental science within recent years has made available to the hypnotic investigator a large number of experimental methods and devices which he may utilize at once with little or no modification. Lastly there is reason to believe that a kind of renaissance in hypnotic research is actually on its way. At several centers of learning and research in this country alone there exists a vivid appreciation of the possibilities in this direction. From at least two of these is already appearing at fairly regular intervals a succession of papers describing really scientific and adequately controlled hypnotic investigations. It is not inconceivable that, profiting by its checkered past, hypnotism may one day occupy an enviable scientific position.

A PHARMACOLOGICAL APPRECIATION OF REFERENCES TO ALCOHOL IN THE HEBREW BIBLE

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Introduction

The alcohol problem in the United States is at present of universal interest. While the question has been widely discussed from the sociological, psychological, political and legal aspects, the whole subject from the scientific point of view is primarily a medical one, and, more accurately speaking, belongs to the domain of pharmacology. No apology is therefore necessary for any investigation of a pharmacological character which may tend to throw more light on the subject, be that investigation of an experimental character or of a historical nature. The historical approach to the study of medical problems is now being recognized more and more as of great value in establishing a proper perspective of a given subject and often providing useful empirical data for carrying on experimental investigations. For this reason, the present sketch is deemed to fill a definite need, namely, to furnish reliable information concerning a subject which has been greatly misunderstood. No apologies are required for a scientific inquiry into references to wine and other alcoholic liquors mentioned in the Bible because of the incontestable fact that this literary work is truly the Book of Books, one which has been and is being read by the largest number of human beings in the world, and a book which has been translated into a greater number of languages than any other work. This universal appeal of the Book of Books may, on superficial consideration, be regarded as an argument against any new publication dealing with its contents as being superfluous. Such an argument, however, is not a valid one for two very good reasons. In the first place, the Bible has been dragged into the prohibition controversy by persons prompted more by acrimonious zealotry and bigotry than by a desire to understand correctly the work which they are quoting. In the second place, it is a platitude, which nevertheless is worth emphasizing, that no translation of any literary masterpiece can adequately convey either the sense or the spirit of the original text and, in the case of the Old Testament, references to alcohol have been based on quotations or misquotations from English translations of the Hebrew, many of which are preposterous and nonsensical. To appreciate fully the truths and the beauties of the Hebrew Tenach (Bible), it is absolutely necessary to have at least some acquaintance with the original text. To quote from an illustrious writer on the subject: "It must be read in Hebrew, that is to say, in accordance with the *spirit* of that language. It describes but little, but through the rich significance of its verbal roots, prints in the word a picture of the thing." A thorough acquaintance with the etymological denotations of these roots is essential for the adequate grasp of the complete idea or thought expressed in its consonants and simple words. "It only joins for us predicate to subject and sentence to sentence; but it presupposes the listening soul, so watchful and attentive that the deeper sense and profounder meaning, which lie not upon but beneath the surface, may be supplied by the logical and independent action of the mind itself. It

is, as it were, a semi-symbolic writing."[1]

In the present paper it is proposed, in the first place, to recapitulate briefly the status of pharmacological and toxicological knowledge concerning alcohol and, in the second place, in the light of such knowledge to examine critically the more important references to wine and liquor mentioned in the various books of the Old Testament. Such a critical study of the Bible will not be based on the reading of any one authorized version, but on a comparative study of various original texts and available translations as well as on philological investigations concerning the various terms encountered, out of which the most straightforward and clearest interpretations will be selected in the light of the latest pharmacological and medical data. It is hoped that such a contribution will be found useful both by specialists in the natural and medical sciences and by general students of Biblical history and philology.

Physiological Considerations

Although ethyl alcohol is generally discussed along with other alcohols in text-books on pharmacology, this particular compound is in a sense really not a drug at all and may be classed physiologically as a normal product of metabolism and, to a certain extent, as a food. Thus, a Japanese investigator, Morie Aoki,[2] has found that ethanol is a normal product of certain living cells. Again, both physiologists and pharmacologists are agreed that it is an excellent food in the sense of being a source of energy. It is completely oxidized in the body when small quantities are taken internally, and in that way supplies energy to the living organism. Thus, Starling,[3] in his "Human Physiology," states:

> When alcohol is taken by man in moderate quantities, the greater part of it undergoes oxidation and leaves the body as carbon dioxide and water; about two per cent., which escapes oxidation, is excreted unaltered by the lungs and kidneys. This oxidation of alcohol is a result of true utilization, since the addition of a certain amount of alcohol to the body does not result in an increased output of carbon dioxide. In small quantities, therefore, alcohol can act as a food.

This function, however, is not so important in normal individuals as in certain diseased conditions, especially in fevers and certain constitutional diseases like diabetes. In fevers, much larger quantities of alcohol are oxidized and liberate sufficient energy to take the place of at least a part of ordinary diet. According to Sollmann,[4] to quote from his standard reference book on pharmacology in connection with the use of alcohol in exhausting fevers:

> The intelligent and discriminate employment of alcohol should be useful in these conditions; its indiscriminate use would doubtless do more harm than good. The beneficial effects are probably mainly nutrient, due to the direct *food value of alcohol*, and to the stimulation of the digestion and absorption of other foods. This not only conserves the general nutrition of the patient but also increases the output of the exhausted heart. The pulse becomes stronger and more regular. The altered distribution of the blood by the mildest degrees of alcohol action would also be beneficial. The dilation of the cutaneous vessels removes the blood from the atonic, and therefore congested, internal organs and lessens venous distention of the heart. It would also tend to lower the temperature, although the antipyretic effect is but small. The narcotic action of the alcohol is useful by quieting the febrile excitement, thus reducing the demands on the strength of the patient.

In diabetes mellitus, alcohol, as would be expected, acts favorably as an easily digested food, supplying the place of the sugar and diminishing the excessive demand on proteins and thus lessening the risk of acidosis. This has been shown to some extent by the work of Benedict and

[1] Hirsch, "The Nineteen Letters," trans. by Drachman, Funk and Wagnalls, 1899.

[2] *J. Biochem.* (Japan), v, p. 71, 1925.

[3] "Human Physiology," p. 566, 1926.

[4] "Manual of Pharmacology," p. 640, 1922.

Török,[5] who found that the replacement of fifty to eighty grams of food fat by equivalent quantities of alcohol lessens the excretion of sugar, acetone and nitrogen. Neubauer[6] also found alcohol useful in diabetes, although other writers, such as Mosenthal and Harrop,[7] found that it was not able to replace protein or fat in conserving a nitrogen balance.

Pharmacological Résumé

The salient facts concerning the pharmacological action of ethyl alcohol are well established and are unanimously agreed upon by all investigators in pharmacology. Ethyl alcohol is a drug or chemical acting primarily upon the *central nervous system.* In the course of its action, depending on the dose, two stages can be distinguished. After small doses a sense of well-being and of "stimulation," or excitement, is noted. The feeling of well-being, or euphoria, is a characteristic feature of the action of the drug and manifests itself in a sense of comfort and relaxation, a feeling of greater confidence in oneself, greater freedom of speech and an increased buoyancy of spirits, so that a person who may be depressed becomes more sanguine and cheerful. This sense of "stimulation" produced by alcohol has been regarded by Binz,[8] one of the prominent earlier investigators in the field, as due to a true stimulation of nervous elements. Bunge,[9] however, who was another eminent worker in the field, regarded the "stimulation" as being due to a release of excessive inhibitions in the nervous system, allowing a freer play of psychological reactions. More recent and extensive psycho-pharmacological investigations, by Rivers,[10] Kraepelin,[11] Jacobi[12] and Benedict,[13] have amplified our knowledge concerning the action of ethanol. According to Kraepelin, the primary stimulating effect of ethyl alcohol is that it facilitates mechanical work through a stimulation of motor impulses, as indicated by experiments with the dynamometer. On the other hand, Kraepelin found that such mechanical processes as simple reactions, repetition of words, reading, etc., are made at the expense of the more complex mental processes and associations, so that very accurate intellectual work and finer judgments are impaired. The American investigators, Dodge and Benedict, found that ethyl alcohol not only depresses the sensory reactions, but does not produce any definite stimulation even of simple mechanical performance. All investigators, however, are agreed that whether the primary "stimulation" of the brain by alcohol be a true stimulation or merely a release of inhibitions, the effect upon the psychic state of the subject is to produce a sense of euphoria, or well-being, which is of great therapeutic value in cases of nervous strain, melancholia and other depressive states. Large or excessive doses of ethyl alcohol, however, exhibit the secondary stage of its pharmacological action, namely, the loss of coordination, stupor and, eventually, a complete paralysis of the central nervous system, leading to coma and death.

In addition to the effects upon the central nervous system, one of the most important properties of alcohol is its effect on the circulation. Here, again, all pharmacologists agree a stimulating effect is produced. This is due partly

[5] *Bioch. Centr.*, v, p. 1916, 1906.

[6] Cited by Sollmann.

[7] *Arch. Int. Med.*, xxii, p. 750, 1918.

[8] *Arch. f. Exper. Path. u. Pharmakol.*, vi, p. 312, 1877.

[9] "Die Alkohol Frage," Leipzig, 1887.

[10] "The Influence of Alcohol on Fatigue," London, 1908.

[11] *Bioch. Bull.*, v, p. 223, 1916.

[12] *Arch. f. Exper. Path. u. Pharmakol.*, xxxii, p. 49, 1893.

[13] *Jour. Amer. Med. Assoc.*, lvi, p. 1424, 1916.

to the narcotic action of alcohol on the cerebrum, partly to a stimulating effect upon the medulla, namely, on the vagus and the vasomotor centers, and partly to an improved nutrition of the heart as a consequence of dilatation of the coronary vessels. Clinically, small and moderate doses of alcohol produce a slight increase in blood pressure, a slight slowing of the heart beat, a vasodilatation of the peripheral vessels and diuresis. The action of alcohol upon the circulation is a rapid one, so that one of the cardinal therapeutic indications for its use is as a stimulant in collapse or shock.

From the toxicological point of view, alcohol, in respect to its action on the central nervous system, stands midway between hypnotics and general anesthetics. When taken in moderate doses, it is often conducive to sleep, while in larger doses it was commonly employed as an anesthetic for surgical operations before the discovery of ether and chloroform anesthesia. Furthermore, it is well known to every clinician, as well as pharmacologist, that small doses of alcohol often improve digestion, partly through a reflex action on the salivary and gastric secretions and partly through their psychic effects. Ethanol is quickly absorbed from the stomach and in sensitive subjects such absorption is rapidly followed by peripheral vasodilatation and flushing of the face and head.

The effects of alcoholic intoxication are too well known to be described. Acute alcoholism of the extreme type is characterized by delirium tremens and followed by coma and death. Chronic poisoning is manifested by a variety of symptoms and leads to degenerative changes in the nervous, cardiovascular and renal systems. Chronic congestion of the skin and mucous membranes and digestive disturbances are also very common in habitual alcoholics.

The principal therapeutic indications of alcohol may be summed up as follows:

(1) As a food, more particularly in fevers and certain constitutional diseases like diabetes.

(2) As a valuable stimulant in acute circulatory conditions.

(3) As a rapid and efficient stimulant in cases of collapse and shock.

(4) In small doses, as a useful agent in treatment of anorexia and certain forms of indigestion.

(5) As a vasodilator and diaphoretic in certain infections, such as coryza, grippe, etc.

(6) As a mild hypnotic in selected cases.

(7) As an invaluable sedative of the nervous system, promoting general relaxation and thus protecting against excessive nervous strain.

(8) As an analeptic agent in psychiatric conditions, more particularly melancholia and other depressive states.

Etymological Consideration[14]

The English world *alcohol,* as is well known, is of Semitic origin. It is an Arabic word, consisting of two parts, *al* and *koh'l, al* being the definite article and *koh'l* denoting a fine black powder, in reality a sulphide of antimony, or galena, obtained by sublimating antimonium compounds. Alcohol, in Arabic, thus meant originally a very fine product of sublimation. The powder was used by ladies as a cosmetic for penciling the eyebrows. Later, the term was applied to "distillate" or highly refined spirits, obtained from wine. The use of the same term for a sublimate and a distillate is, from a chemical point of view, not at all incongruous. In Spanish, the word alcohol still retains two meanings, the older one denoting a pigment or dye and the later one denoting alcohol proper.

Our colloquial term "booze" is, according to Berthold Laufer,[15] also partly

[14] *Cf.* Lexica of Gensenius, Fürst, Ben Yehuda, and Aruch Completum of Jastrow.

[15] *Jour. Amer. Med. Assoc.*, xlix, p. 56, 1929.

of Oriental origin. There is an old Persian-Arabic word, *bōza* or *buza*, denoting an alcoholic beverage, made from millet, barley or rice, which is widely distributed over Asia, Europe and Northern Africa. This word, according to Laufer, is very possibly the same as our American *booze*.

The term alcohol is not found in the Old Testament, although it has been introduced into modern Hebrew. In the Bible, however, we find a wealth of terms denoting wine and other alcohol-containing liquors. The etymological significance of these is of great interest and is briefly considered in this place. *Yayin* is the term for wine most frequently occurring in the Hebrew Bible. It is always applied to wine made from grapes and not to other so-called wines, prepared from various fruits or berries. The etymology of this word, according to Rabbi S. R. Hirsch,[16] is probably from the Hebrew root *yanah*, which means *to oppress*. Thus, in Zephaniah iii: 1, we read *ha-'ir ha-yonah*, meaning *the oppressing city*. Again, in Jeremiah xlvi: 16 and l: 16, we find the expression *hereb yo-nah*, which may be rendered *the oppressive sword*. The term *to oppress* is, of course, figuratively identical with the physical word *to press* and in the case of another Hebrew root, *lahaṣ*, we find both meanings. Thus in Numbers xxii: 25 and II Kings vi: 32, the verb *lahaṣ* means *to press* or *squeeze*, while in Exodus iii: 9; xxiii: 9, and Judges i: 34, the same word is used in a sense of *oppressing*. The cognate root to *yayin* in Arabic, *yawan*, actually denotes *to press*. It is therefore quite obvious that the word *yayin* refers to the *expressed juice* of the grape.

The expression *grape juice*, or *blood of grapes*, as referring to wine, also occurs in the Old Testament. Thus, in Genesis xlix: 11, we read,

> He washeth his garments in wine (*yayin*), and in the *blood of grapes* his clothes.

and in Deuteronomy xxxii: 14,

> Of the *blood of the grape* thou drankest unmixed wine (*hōmĕr*).

Another term for wine found in the Hebrew Bible is *tirôš*. This is usually applied to a stronger form of wine than *yayin* and may be translated *strong wine*. The root of *tirôš* is probably from the Hebrew *yārăš*, which means *to seize possession of* or *to inherit* and refers probably to the overpowering effects of alcohol on the head. According to Hirsch, *tirôš* may also come from the root *yārăš*, *to inherit*, denoting the inheritance, or the "leavings," of the grape after it has been squeezed. A popular derivation of the word *tirôš* is found in the Talmud (Yoma 76: b). Here we have a play on words of similar sound, one being *tirôš*, denoting *wine*, and the other *rōš*, denoting *poverty*.

> The wise men say, "He who indulges in wine (*tirôš*) becometh poverty-stricken (*rôš*)."

Still another term for an alcoholic liquor found in the Hebrew Bible is *šēkhor*, generally translated *strong drink*. The same root gives the Hebrew word which denotes *drunkenness*. Hirsch calls attention to the phonetic relation between the roots *šēkhor* and *šèquer*, the former denoting *strong drink* and the latter, *a lie*, and he points out the similarity of the two psychological states, drunkenness on the one hand, and distortion of truth, or lying, on the other. Philologically, however, the root *šēkhor* is generally correlated with the root *śākhar*, meaning *to shut up* or *to be stopped up*. Thus, in Genesis viii: 2, we read,

> The fountains also of the deep, and the windows of heaven were *stopped* (*wayyi-śokhrû*).

And in Psalm lxiii: 12.

> The mouth of those that speak falsehood *shall be stopped*.

[16] "Kommentar zum Pentateuch," loc. Gen. ix. 21.

The idea of drunkenness here emphasized is that of the *stopping up* of the normal channels of reasoning. A further proof of the relation between *šĕkhor* and the root *śākhar* is that, in Isaiah xix: 10, the word *to stop up* is actually written with the letter *śin*. Some translations of this passage take the word *śākhar* from the root meaning *to hire* and read as follows,

> They that *earn wages* shall be grieved in soul.

In the new translation of the Jewish Publication Society, 1917, however, the denotation of *stopping up* is chosen as more appropriate and we read the following,

> All they that make *dams* shall be grieved in soul.

Still another word for wine found in the Bible is *hōmĕr*, really denoting *must* or *fermenting grape juice*, from the root *hāmár, to be in ferment* or to be *agitated*. Thus we find this word in Deuteronomy xxxii: 14,

> Thou drankest unmixed wine (*hōmĕr*).

And in Isaiah xxvii: 2,

> Sing ye a song of the vineyard of excellent wine (*hōmĕr*).

In addition to the meaning *fermentation*, the root *hamár* also signifies *to muddle*, and a noun, *hōmer*, derived from the same root, denotes *mud* or *mire*. Compare Isaiah x: 6 and Job xxx: 19:

> I give him a charge . . . to render them trodden down like the *mire* of the streets.—He hath cast me into the *mire*.

This idea of *muddling* is regarded by some as the basic significance of *hōmĕr, wine*, referring to the muddling or clouding of the mind by too much drink.

Two other words denoting wine are found in the Old Testament. These are *mésĕkh* and *mésĕg*, both from closely allied roots, each denoting *mixing*. These terms are applied not to pure wine but to *mixed* wine or wine which has been doctored with spices, etc. The word *mézĕg* occurs in Canticles vii: 3, in which we read,

> Thy navel is like a round goblet which lacketh not the mixed wine (*mésĕg*).

and the word *mésĕkh*, which also signifies a mixed or doctored drink, is found in Psalm lxxv: 9,

> The wine (*yayin*) foameth, it is full of mixture (*mésĕkh*).

Examination of Biblical Passages

(1) *Wine as Food*

The Hebrew Bible contains some two hundred passages referring to wine, strong drink and other alcoholic beverages. By far the largest number of such references speak of wine, or fermented grape juice, as an agricultural product universally utilized as food or harmless beverage. Still other numerous passages in the Old Testament mention wine in connection with sacrificial rites, as an offering symbolizing one of man's most cherished and valuable material possessions. It would require too much space to quote all such passages in reference to wine. The following, however, will serve as excellent examples, indicating the status of wine as food or daily beverage among the ancient Hebrews and other peoples mentioned in the Bible.

> And Melchizedek, king of Salem, brought forth bread and wine (*yayin*): and he was the priest of the most high God.—*Genesis xiv: 18.*

> Therefore God give thee of the dew of heaven, and the fatness of the earth, and plenty of corn and wine (*tirôš*).—*Genesis xxvii: 28.*

> And with the one lamb a tenth deal of flour mingled with the fourth part of an hin of beaten oil; and the fourth part of an hin of wine (*yayin*) for a drink offering.—*Exodus xxix: 40.*

> And the meat offering thereof shall be two tenth deals of fine flour mingled with oil, an offering made by fire unto the LORD for a sweet savour: and the drink offering thereof shall be of wine (*yayin*), the fourth part of an hin.—*Leviticus xxiii: 13.*

> And the fourth part of an hin of wine (*yayin*) for a drink offering shalt thou prepare

with the burnt offering or sacrifice, for one lamb.—*Numbers xv: 5.*

And He will love thee, and bless thee, and multiply thee: He will also bless the fruit of thy womb, and the fruit of thy land, thy corn, and thy wine (*tîrôš*).—*Deuteronomy vii: 13.*

That I will give you the rain of your land in its due season, the first rain and the latter rain, that thou mayest gather in thy corn, and thy wine (*tîrôš*), and thine oil.—*Deuteronomy xi: 14.*

And thou shalt bestow that money for whatsoever thy soul lusteth after, for oxen, or for sheep, or for wine (*yayin*), or for strong drink (*šēkhar*), or for whatsoever thy soul desireth: and thou shalt eat there before the LORD thy God, and thou shalt rejoice, thou, and thine household.—*Deuteronomy xiv: 26.*

Yet there is both straw and provender for our asses; and there is bread and wine (*yayin*) also for me, and for thy handmaid, and for the young man.—*Judges xix: 19.*

And when she had weaned him, she took him up with her, with three bullocks, and one ephah of flour, and a bottle of wine (*yayin*), and brought him unto the house of the LORD in Shiloh.—*I Samuel i: 24.*

And, behold, I will give to thy servants, the hewers that cut timber, twenty thousand measures of beaten wheat, and twenty thousand baths of wine (*yayin*), and twenty thousand baths of oil.—*II Chronicles ii: 9.*

Ho, every one that thirsteth, come ye to the waters, and he that hath no money; come ye, buy, and eat; yea, come, buy wine (*yayin*) and milk without money and without price.—*Isaiah lv: 1.*

Thou shalt sow, but thou shalt not reap; thou shalt tread the olives, but thou shalt not anoint thee with oil; and sweet wine (*tîrôš*), but shalt not drink wine (*yayin*).—*Micah vi: 15.*

Now that which was prepared for me daily was one ox and six choice sheep; also fowls were prepared for me, and once in ten days store of all sorts of wine (*yayin*).—*Nehemiah v: 18.*

And I will bring again the captivity of my people of Israel, and they shall build the waste cities, and inhabit them; and they shall plant vineyards, and drink the wine (*yayin*) thereof; they shall also make gardens, and eat the fruit of them.—*Amos ix: 14.*

Until I come and take you away to a land like your own land, a land of corn and wine (*tîrôš*), a land of bread and vineyards.—*Isaiah xxxvi: 17.*

And the earth shall respond to the corn, and the wine (*tîrôš*), and the oil; and they shall respond to Jezreel.—*Hosea ii: 24.*

Yea, the LORD will answer and say unto His people, Behold, I will send you corn, and wine (*tîrôš*), and oil, and ye shall be satisfied therewith.—*Joel ii: 19.*

Come, eat of my bread, and drink of the wine (*yayin*) which I have mingled.—*Proverbs ix: 5.*

And the king appointed them a daily provision of the king's meat, and of the wine (*yayin*) which he drank.—*Daniel i: 5.*

Go thy way, eat thy bread with joy, and drink thy wine (*yayin*) with a merry heart; for God now accepteth thy works.—*Ecclesiastes ix: 7.*

(2) *Wine as a Heart Stimulant*

One of the most important therapeutic indications for administration of alcohol in medical practice is in circulatory collapse, or syncope, in which cases its rapidly stimulating effects may be life-saving. While the exact mechanism of its action in such cases is a complicated one, as already discussed in the pharmacological section, the favorable results of alcoholic stimulation in such acute cardiac and other circulatory conditions are recognized by all physicians. How tersely, yet accurately, is this fact described in the Psalms! Here we read (Psalm civ: 15),

Wine *cheereth*—that is, stimulates—the heart of feeble man (*'enoš*).

The word *sāmah, to cheer,* is closely related, according to the rabbis, to the root *sāmah, to sprout* or *blossom.* Wine stimulates or brings fresh energy and makes blossom the exhausted heart. The Psalmist warns us, however, that such a stimulation is but transient and that the real source of the heart's strength must be proper food,

But it is bread which giveth *sustenance* to a man's heart.

Every pathologist is well aware that two of the most important causes of myocarditis, or degeneration of the heart muscle, are alcohol and syphilis. Excesses *in Baccho et Venere* are responsible for numerous deaths from heart disease. In Hosea (iv: 11), a single line states with marvelous scientific insight

these two most important etiological factors of myocardial degeneration,

> Whoredom and wine and new wine take away the heart.

A third vice conducive to degeneration of the arteries and weakening of the heart is often classed with the two preceding, namely, gluttony. In this connection, compare Proverbs xxiii: 20,

> Be not among winebibbers: among riotous eaters of flesh.

The well-known association of alcohol and dissipation is succinctly stated in the Midrash (Bamidbor Rabba 10: 3),

> Wherever there is drunkenness, there is also incest.

The description of Nabal's illness and death, given in I Samuel xxv: 36–38, is of considerable pathological interest. We read that this individual was addicted to excessive drinking to the extent of becoming unconscious. Such repeated excesses evidently affected his heart and blood vessels, for an acute emotional crisis brought on an apoplectic stroke and death. The following is the Biblical account:

> And Abigail came to Nabal; and, behold, he held a feast in his house, like the feast of a king; and Nabal's heart was merry within him, for he was very drunken: wherefore she told him nothing, less or more, until the morning
>
> But it came to pass in the morning, when the wine was gone out of Nabal, and his wife had told him these things, that *his heart died within him, and he became as a stone.*
>
> And it came to pass about ten days after, that the LORD smote Nabal, that he died.

(3) *Exhaustion and Shock*

The beneficial effects of wine and alcohol in shock and other states of great exhaustion were well known in ancient times. The following passages in the Bible give proof of this:

> Give strong drink unto him that is about to perish.—*Proverbs xxxi: 6.*

> They say to their mothers, Where is corn and wine? when they swooned as the wounded in the streets of the city.—*Lamentations ii: 12.*

> The king said unto Ziba, What meanest thou by these? And Ziba said, The asses be for the king's household to ride on; and the bread and summer fruit for the young men to eat; and the wine, that such as be faint in the wilderness may drink.—*II Samuel xvi: 2.*

(4) *Effects on the Nervous System*

Ethyl alcohol, in common with all alcohols, exerts its principal pharmacological action on the central nervous system. It is therefore gratifying to find that many of the passages referring to wine and alcoholic liquors in the Hebrew Bible dwell in particular on the various neurological and psychological effects of drinking.

The striking *loss of motor coordination,* or staggering, produced by alcohol, is vividly pictured in Psalm lx: 5:

> Thou hast made Thy people to see hard things; Thou hast made us to drink the wine (*yayin*) of staggering.

Again, in Isaiah xxix: 9, we read:

> Stupefy yourselves, and be stupid! Blind yourselves, and be blind! ye that are drunken, but not with wine (*yayin*), that stagger, but not with strong drink (*šēkhor*).

The *hypnotic and anesthetic effects* of liquor are mentioned in Genesis xix: 32, 33:

> Come, let us make our father drink wine (*yayin*), and we will lie with him, that we may preserve seed of our father.
>
> And they made their father drink wine (*yayin*) that night . . . and he knew not when she lay down, nor when she arose.

The deep sleep produced by wine is also indicated by the story of Noah, Genesis ix: 24:

> And Noah awoke from his wine (*yayin*), and learned what his younger son had done unto him.

The story of Noah and his vineyard is a direct refutation of the alien

thoughts read into the Bible by those who assert that the wine of the Old Testament was not alcoholic. Noah not only drank wine, but also became intoxicated and, furthermore, gave an excellent demonstration of the sleep-producing potency of liquor (Genesis ix: 20, 21, 22, 24):

> And Noah began to be an husbandman, and he planted a vineyard:
> And he drank of the wine (*yayin*), and was drunken; and he was uncovered within his tent.
> And Ham, the father of Canaan, saw the nakedness of his father, and told his two brethren without. . . .
> And Noah awoke from his wine (*yayin*), and learned what his younger son had done unto him.

The ancient Hebrews, in common with other nations of antiquity, employed alcohol for deadening pain just as anesthetics are employed to-day. Pharmacologically large doses of alcohol deaden the pain areas in the cerebrum and produce unconsciousness, or general anesthesia, like ether and chloroform. This property was made use of in connection with capital punishment. The Hebrews inflicted the death penalty when warranted by the nature of the crime committed, but in all cases it was considered a duty to render the infliction of death in a merciful and painless manner. For this reason, the condemned were made to drink large quantities of liquor or strong wine, which were often also mixed with various narcotics. Thus, in the Talmud (Sanhedrin 43 a), we learn that when a person was about to be put to death, he was given to drink a cup of wine with a dose of *lebônah*. Again, in the Midrash Rabba (Shemoth Rabba 84), we find a statement that all those doomed to capital punishment were given wine to drink that they might not suffer. It is interesting to note that certain passages in the Old Testament also refer to this custom. Thus, in Amos ii: 8, we read:

> And they lay themselves down upon clothes laid to pledge by every altar, and they drink the wine (*yayin*) of the condemned in the house of their god.

One of the most important and undisputed therapeutic effects of alcoholic beverages is in certain *psychiatric conditions* characterized by depression, such as melancholia, etc. In this connection, the famous passage in Proverbs xxxi: 6, 7, is of special interest:

> Give strong drink (*šēkhor*) unto him that is about to perish, and wine (*yayin*) unto the bitter in soul.
> Let him drink, and forget his poverty, and remember his misery no more.

The stimulating effects of wine in depressive states are also described in Ecclesiastes x: 19:

> A feast is made for laughter, and wine (*yayin*) maketh glad the life.

In discussing the cerebral effects of alcohol in the pharmacological section of this paper, mention was made of the moot question in regard to the stimulating effects of alcohol on the brain. It was pointed out that, according to the Binz school, small doses produced a true primary stimulation of the nervous elements, whereas, according to Schmiedeberg and his school, such a stimulation was really due to a release of inhibitions. Several passages in the Hebrew Bible hint at the pseudo-stimulation produced by alcohol. Thus, in Proverbs xx: 1, we read,

> Wine (*yayin*) is a mocker, strong drink (*šēkhor*) is raging; and whosoever is *deceived* thereby is not wise.

The loss of self-control, the boastfulness, recklessness and display of emotionalism after excessive drink are but too well known. Many passages in the Bible refer to such states. Thus, in Habakkuk ii: 5, we find this description,

> He transgresseth by wine (*yayin*), he is a proud man.

Again, in Isaiah v: 22 and xxii: 13, we read:

Woe unto them that are mighty to drink wine (*yayin*), and men of strength to mingle strong drink (*šēkhar*).

And behold joy and gladness, slaying oxen, and killing sheep, eating flesh, and drinking wine (*yayin*); let us eat and drink, for to-morrow we shall die.

While wine and alcohol have their proper place in therapeutics in stimulating the spirits of the depressed and hypochondriac, the Bible clearly indicates, in agreement with the latest findings of experimental psychology, such as those of Kraepelin, Benedict and others, that the imbibition of alcoholic beverages is not conducive to very accurate psychological performance, either in the neuro-muscular sphere or in the higher intellectual processes of the cerebrum. It is interesting to note that the drinking of wine or liquor is *prohibited to leaders* in Israel, whether legislative or judicial or executive or purely religious, during the performance of their respective duties or tasks. In Leviticus (x: 9) is an injunction given to the *priests* not to partake of wine or strong drink when going into the tabernacle of the congregation for the performance of religious rites.

Do not drink wine (*yayin*) nor strong drink (*šēkhar*), thou, nor thy sons with thee, when ye go into the tabernacle of the congregation, lest ye die: it shall be a statute for ever throughout your generations.

Again, in Ezekiel xliv: 21, we read:

Neither shall any priest drink wine (*yayin*) when they enter into the inner court.

The king, whose name, according to a beautiful Hebrew legend, is a mnemonic of his duties, is also warned to abstain from alcoholic excesses. The Hebrew word for king, *MeLeK,* consists of three consonants, M, L and K. Each of these letters, according to the Rabbis, is the abbreviation of a preposition: M, standing for *min,* denotes *from*; L is the Hebrew preposition *to*; and K is the comparative particle, meaning *as* or *like*. The Hebrew ideal of a king was that of an exalted paragon, a personage *from whom* authority came, to *whom* every one appealed for justice and a noble character *like whom* his subjects should try to be. In order to perform his functions most faithfully, it is well for the king not to drink.

It is not for kings, O Lemuel, it is not for kings to drink wine (*yayin*); nor for princes strong drink (*šēkhar*).—*Proverbs xxi: 4.*

Isaiah denounces the priests and the *prophets,* teachers of the people and their spiritual leaders, for erring in judgment and other duties through their devotion to drink.

But they also have erred through wine (*yayin*), and through strong drink (*šēkhar*) are out of the way; the priest and the prophet have erred through strong drink (*šēkhar*), they are swallowed up of wine (*yayin*), they are out of the way through strong drink (*šēkhar*); they err in vision, they stumble in judgment.—*Isaiah xxviii: 7.*

(5) *Toxicological Phenomena*

A wealth of information is to be gleaned from the Old Testament concerning both milder forms and extreme manifestations of alcoholic intoxication.

The congestive and inflammatory effects of habitual drink are described in Isaiah v: 11:

Woe unto them that rise up early in the morning, that they may follow strong drink (*šēkhar*); that continue until night, till wine (*yayin*) inflame them!

Exaggerated self-confidence and boastfulness are described in Isaiah v: 22:

Woe unto them that are mighty to drink wine (*yayin*), and men of strength to mingle strong drink (*šēkhar*).

and again in Habukkuk ii: 5,

He transgresseth by wine (*yayin*), he is a proud man.

Garrulousness and loud talk are mentioned in Zechariah ix: 15:

They shall drink, and make a noise as through wine (*yayin*); and they shall be filled like bowls, and as the corners of the altar.

Inflammation of the mucous membranes, more particularly, of the eyes, is cited in Genesis xlix: 12,

His eyes shall be red with wine (*yayin*), and his teeth white with milk.

The revolting picture of the tippler's gastritis is strongly depicted in Jeremiah xxv: 27 and xlviii: 26:

Drink ye, and become drunken, and vomit, and fall, and rise no more.

Make him drunken; for he magnified himself against the LORD; and Moab shall wallow in his vomit and he also shall become an object of derision.

The deteriorating effects on the vision, as well as on the brain, are mentioned in Isaiah xxix: 9:

Blind yourselves, and be blind! ye that are drunken.

Two verses from the prophets are of unusual interest because of their vivid description of the extreme and acute alcoholic intoxication. To appreciate these, a careful study and accurate translation of the original text are necessary. Jeremiah li: 39, in the authorized version, is translated thus:

In their heat I will make their feasts, and I will make them drunken, that they may rejoice, and sleep a perpetual sleep, and not wake, saith the LORD.

The widely used Jewish translation by Leeser gives practically the same interpretation with perhaps a slightly clearer meaning:

When they are heated will I prepare their drinking-feasts, and I will make them drunken, in order that they may be joyful, and sleep a perpetual sleep, and not awake again, saith the LORD.

This verse, however, in the light of the most recent philological researches is more correctly and appropriately to be construed as follows: The Hebrew *b'hummam*, ordinarily rendered as *in their heat*, can be equally well derived from the root *hemah*, meaning *poison*, and the verb *ya'alozu*, ordinarily taken from the root *'alaz, to rejoice*, may be interpreted, according to another Massoretic reading, as coming from the root *'alaf*, meaning *to tremble*.[17] The sense of the passage is therefore as given by the latest translation, published under the auspices of the Jewish Publication Society:[18]

With their *poison* I will prepare their feast, and I will make them drunken, that they may be *convulsed*, and sleep a perpetual sleep, and not wake, saith the LORD.

Here we have a graphic description of delirium tremens, or convulsions, induced by excessive quantities of alcohol, which are followed by coma and death.

Another passage describing the coma induced by alcoholic intoxication of extreme degree is to be found in Nahum iii: 11. Here the verb root *'alam*, rendered in the authorized version *to be hidden*, has also in Hebrew the well-substantiated meaning of *fainting* or *swooning*, which gives a much more grammatical and pharmacologically more appropriate translation:

Thou also shalt be drunken, thou shalt *swoon*; thou also shalt seek a refuge because of the enemy.

(6) *Proverbs xxiii: 29–35*

This passage in the Book of Proverbs is a classical description of the psychological and pharmacological effects of excessive alcoholic drinking and deserves a more detailed examination on that account. Certain portions of this description, as given in most translations of the Bible, are remarkably obscure and almost incomprehensible. A careful study of the Hebrew text, however, in the light of both physiological and phar-

[17] Kittel, Edition of Hebrew Bible.

[18] New English Trans. Hebrew Bible, Philadelphia, 1917.

macological investigation, proves it to be of even greater interest than was ordinarily supposed. The late Professor Paul Haupt has called attention to several difficulties encountered in the translation of these verses in a paper, published in the *Journal of Biblical Literature*, which was intended to expose the fallacy of certain individuals who attempted to prove that wine referred to in the Bible was non-alcoholic, and some of his Hebrew renditions are extremely enlightening.[19]

29 Who hath woe? who hath sorrow?
Who hath contentions? who hath babbling?
Who hath wounds without cause?
Who hath redness of eyes?
30 They that tarry long at the wine;
They that go to seek mixed wine.
31 Look not thou upon the wine when it is red,
When it giveth his colour in the cup,
When it moveth itself aright.
32 At the last it biteth like a serpent,
And stingeth like an adder.
33 Thine eyes shall behold strange women
And thine heart shall utter perverse things.
34 Yea, thou shalt be as one that lieth down in the midst of the sea,
Or as he that lieth upon the top of a mast.
35 They have stricken me, *shalt thou say*, and I was not sick;
They have beaten me, and I felt *it* not:
When shall I awake?
I will seek it yet again.

The most interesting part of this quotation is verse 34, yet it is difficult to make common sense of the English as given above. What is meant by "lying down in the midst of the sea," and still more, how can one "lie upon the top of a mast"? The first question can be easily answered. Professor Haupt calls attention to the fact that the Hebrew expression *leb yam*, the *heart of the sea*, expresses figuratively the *bosom of the sea*, that is, the waves of the high sea. The correct translation is therefore, *as one that is sailing on high seas* and consequently nauseated, dizzy and seasick. The Hebrew expression *šôkeb be-rôš ḥibbêl*, rendered as "lying on the top of a mast," is even more mystifying. The Hebrew word *rôš*, meaning *head*, has been shown by Professor Haupt to refer in this passage to opium.[20] The powerful alkaloids of opium are obtained by incisions around the *caputa*, or *heads*, of the poppy, *Papaver somniferum*, and the Hebrew word *rôš*, or *head*, in this verse most likely denotes the narcotic poppy head. In the Old Testament, *rôš*, the bitter poison of the poppy head, is repeatedly mentioned in connection with *la'anah*, *wormwood* or *absinthe* (Jeremiah viii: 14; ix: 15, etc.). Again, the expression *mê rôš* is appropriately translated as *juice of the poppy head*. We have already remarked that the Talmud relates that a cup of wine with *lebônah* was given to criminals before their execution. The word *lebônah*, although ordinarily applied to one of the ingredients of incense, is also used in general for a bitter aromatic drug such as opium.

As regards the word *ḥibbêl*, rendered as *mast*, an entirely different translation, more correct philologically and certainly more appropriate pharmacologically, can be given. The word *ḥibbêl* can be grammatically written *ḥobel*, a present participle from the root *ḥābal*, meaning *to bruise, injure, knock out, destroy*. The expression *rôš ḥôbēl*, therefore, means literally the "knock-out" or *injurious poppy* and refers to the stupefying or narcotic effects of opium. Compare the slang expression, "knock-out drops," applied to the powerful hypnotic *chloral*. The author of the Proverbs wishes to convey the idea that an excessive dose of alcohol produces a drunken stupor much like the narcotic effect or stupor of opium or dope. The translation by Professor Haupt vividly sketches the salient features of acute and habitual alcoholism, emphasizing at the same time the similarity of action between alcohol

[19] Haupt, *Jour. Biblical Lit.*, xxxv, p. 75, 1917.

[20] Haupt, *Proc. Amer. Philosoph. Soc.*, April 25, 1915.

and various narcotic drugs. This is exactly in accord with the most modern views of pharmacologists. The narcotics (opium), the hypnotics (chloral), and the general anesthetics (ether and chloroform) are pharmacologically all drugs belonging to one class, the great group of compounds acting primarily upon the brain and central nervous system. Professor Haupt's translation of the lines before us is a grammatically accurate one and, pharmacologically, an astoundingly true and vivid one.

29 Who has woe? and who has misery?
Who has brawls? and who has grief?
Who has wounds without any cause?
And who has dimness of eyes?
30 Those who linger long o'er the wine,
Who come to try the mixture.
31 Look not on the wine that is red,
When it gives its gleam in the cup;
32 It glides down smoothly, but at last
It is like a viper that stings.
33 Thine eyes will see strange things,
Thy heart will blab queer things;
34 Thou'lt feel as one sailing the high seas
Or as one put to sleep by poppy.
35 If they hit me, I was not sore;
If they struck me, I did not feel it.
As soon as I wake from my wine,
I shall surely try it again.

Comment

From the standpoint of modern pharmacology, a critical examination of the numerous Biblical passages cited above leads to some very interesting and delightfully refreshing conclusions. We find in the Hebrew Bible an extraordinarily well-balanced and scientifically up-to-date and complete account of the various physiological, pharmacological and toxicological properties of ethyl alcohol.

Alcoholic beverages in moderation are, strictly physiologically speaking, of some value as *foods,* and the Old Testament affords abundant proof of their having been regarded as such by the ancient Hebrews.

Wine and alcohol, from the standpoint of modern pharmacology, are of unquestionable value as a *medicament* in a series of clinical and pathological conditions, the most important of which are shock, cardiac failure, insomnia, nervous exhaustion and mental depression. The beneficial effects of wine and strong drink, when taken in moderation, for each and every one of these conditions, are unequivocally attested in the Hebrew text. If the modern pharmacologist and practicing physician would include under its medicinal applications the employment of alcohol *pharmaceutically,* as for the extraction and preparation of drugs, for which purpose it has always been indispensable from remote antiquity to the present time, we should fully agree with the epigrammatic dictum of the Talmud, which apostrophizes as follows:

> I, alcohol, am at the head of all medicaments.
> —*Baba Bathra 58, b.*

The dangers of abuse and of excessive drink, however, are just as emphatically described in the Bible as are its medicinal values, and the descriptions of alcoholic poisoning of all degrees have been shown to be unsurpassed in their accuracy and forcefulness. The danger of alcoholic excesses, according to the Book of Books, does not result in the absolute prohibition of the use of alcohol, no more than that of other drugs. The writer, as a pharmacologist, can not refrain from quoting an apt expression frequently employed by his distinguished teacher, Professor John J. Abel, who in his lectures used to say, "The molecule of C_2H_5OH is not distinguished from molecules of other drugs or therapeutic agents by a distinctive and peculiar poison label." All drugs are also poisons. How a given drug will act, whether as a medicament or harmful agent, will depend on dosage, on the patient or subject taking it and on numerous other conditions.[21] Ethyl

[21] Macht, *The Maryland Pharmacist,* p. 187, 1927.

alcohol, or grain alcohol, is but a single member of a large series of chemical compounds known as alcohols, the vast majority of which are very much more poisonous and harmful. In a purely scientific investigation, the author has shown elsewhere that all alcohols of the fatty acid series are intoxicating and their toxicity increases with their molecular weight, with the exception of methanol, or wood alcohol, which, while being lower than ethyl alcohol in the chemical series, is of an especially poisonous nature owing to the formation of destructive compounds in the animal body when it is taken internally.[22] On the other hand, ethyl alcohol is exceptional in its low toxicity because a certain amount of it can be burned up in the body and utilized as a food.[23] An even more remarkable phenomenon has been demonstrated recently by Macht and Leach, who have shown that small doses of wood alcohol combined with grain alcohol produce a mixture which is even more poisonous than methanol in pure form.[24] Macht and Ting[25] have also demonstrated experimentally that even the so-called polyhydric alcohols, such as glycol, glycerine and even the solid mannitol, are, pharmacologically speaking, intoxicating and differ in their narcotic effects from ordinary alcohol and from each other only in respect to dosage. The writer and his coworkers[26] have further demonstrated, in a comparative study of alcohol, caffeine and nicotine, administered in minute doses, comparable to the amounts of these substances taken by human beings in their every-day beverages and in moderate smoking of tobacco, that of the three chemical substances of drugs thus ingested or absorbed the *nicotine was by far the most poisonous.* Next in order came caffeine, and *alcohol was the least harmful.* Such scientific data in regard to alcohol are strikingly in accord with the accounts of its action on man described repeatedly in the universally revered and fascinating literary text before us. The status of fermented grape juice and strong drink, as given in the Bible, may perhaps be most appropriately summarized by two quotations from the text.

> The trees went forth to anoint a king over them: and they said unto the olive tree, Reign thou over us.
>
> But the olive tree said unto them, Should I leave my fatness, wherewith by me they honour God and man, and go to be promoted over the trees?
>
> And the trees said to the fig tree, Come thou, reign over us.
>
> But the fig tree said unto them, Should I forsake my sweetness, and my good fruit, and go to be promoted over the trees?
>
> Then said the trees unto the vine, Come thou, reign over us.
>
> And the vine said unto them, Should I leave my *wine, which cheereth God and man,* and go to be promoted over the trees?—*Judges ix: 8–13.*

> Thus saith the LORD, As the new wine is found in the cluster, and one saith, *Destroy it not; for a blessing is in it:* so will I do for my servants' sakes, that I may not destroy them all.—*Isaiah lxv: 8.*

A pharmacological appreciation of Biblical allusions to alcohol leads us to but a single logical conclusion: the Book of Books is in complete accord with the most modern and advanced experimental data on the subject.

22 Macht, *Jour. Pharm. and Exper. Therap.,* xvi, No. 1, p. 1, 1920.

23 Macht, *American Druggist,* lxxix, No. 3, p. 12, 1929.

24 Macht and Leach, *Proc. Soc. for Exper. Biol. and Med.,* xxvi, p. 330, 1929.

25 Macht and Ting, *Amer. Jour. Physiol.,* lx, No. 3, p. 496, 1922.

26 Macht, Bloom and Ting, *Amer. Jour. Physiol.,* lvi, No. 2, p. 264, 1921.

ON SOME PHASES OF PREVENTIVE ENTOMOLOGY

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One often hears the expression that "most of our major insect pests are of foreign origin," but so far as the writer has been able to learn, actual data bearing on this subject have not been compiled in recent years. Thirty-two years ago Dr. L. O. Howard, in an interesting paper entitled "The Spread of Land Species by the Agency of Man,"[1] discussed the interchange of species between countries, with special reference to insects, and pointed out that of the seventy-three species considered by him to be at that time of prime economic importance, thirty were native to the United States, thirty-seven species had been introduced from foreign countries and six were of doubtful origin. Since that time several pests of great economic importance have found their way to the North American continent, and perhaps some of our own native insects, for one reason or another, have become changed in status in such a way as to require their classification with the pests.

In recent years entomologists have been paying increasing attention to two phases of their profession: quarantine work and the control of pests by the biological method. In both these branches of economic entomology the origin and distribution of plant-feeding insects is of great interest and of fundamental importance. Not long ago the writer had occasion to look into this question, and it was thought that perhaps some of the data secured might be of interest to others.

It is extremely difficult, as I am sure every one recognizes, to determine just what insect pests should and which should not be considered of prime economic importance.

I have started with the assumption that only insects of economic importance are discussed in the various text-books of economic entomology now available. In a few instances I have eliminated insects of obviously minor importance and of restricted distribution, included in these works because of special interest to the author. I have added a few important insect pests found in the western states, such as the black scale, citrophilus mealybug and beet leaf hopper, not generally referred to in text-books. The list so selected was then checked against the Index of Economic Entomology, all those having less than ten references being eliminated. The list thus decided upon I believe may be considered as representing the consensus of opinion of American entomologists as to which insects are of economic importance. Only insects destructive to plants and plant products are included.

By this method a list of 183 species was obtained of which 81 are of undoubted foreign origin, a total of 44.2 per cent. Of the remaining 102 species it is entirely probable that some are of foreign origin. I have made no attempt to consult the latest taxonomic works and it is possible that some of the species designated as native have already been determined by systematists to be of foreign origin, these determinations not yet having found their way into economic literature. The figure indicating that of all insects of economic importance in America 44.2 per cent. are of

[1] *Proc. Am. Ass. Adv. Science*, XLVI, 1897.

foreign origin is, I believe, conservative, and will undoubtedly be enlarged as further studies on geographical distribution are made. Since I am including the entire North American continent instead of the United States proper, that most destructive of pests, the cotton boll weevil, falls in the "native" category. This I have done because it seemed desirable to distinguish between the invasion of pests through commercial exchange and invasion through natural spread brought about, as in the case of the cotton boll weevil, through extension by man of the culture of the host plant in such a way as to bridge the natural barrier to distribution. Such an invasion, from an ecological view-point, does not differ from the spread of a native species within the confines of the United States as exemplified by the potato beetle.

Of the seven orders in which the 183 species of insect pests fall, the Hemiptera have the honor of ranking first in number of species, there being fifty-four in this group, of which twenty-three are introduced and thirty-one are native. Ranking next to the Hemiptera are the Lepidoptera with fifty species, of which twenty-three are introduced and twenty-seven are native. Following in order of numbers are the Coleoptera with forty-two species, of which nineteen are introduced and twenty-three are native; the Diptera with eleven, of which five are introduced and six are native; the Hymenoptera with eight, of which four are introduced and four are native; the Orthoptera with seven, all of which are native, and the Thysanoptera with six, of which two are introduced and four are native. As previously stated, many of the species designated as native would more properly be considered as of doubtful origin.

Taking the *number* of introduced species, the Hemiptera and Lepidoptera tie for first place with twenty-three species each, followed by Coleoptera with twelve; Diptera with five, Hymenoptera with four, Thysanoptera with two and Orthoptera with none.

In *percentage* of introduced to total number of species of that order classed as pests, the ranking is as follows: Hymenoptera, 50 per cent.; Lepidoptera, 46 per cent.; Diptera, 45.4 per cent.; Coleoptera, 42.5 per cent.; Hemiptera, 42.5 per cent.; Thysanoptera, 33.3 per cent., and Orthoptera with none. While the writer admits that this ranking may be questioned because of the somewhat arbitrary method of selecting the species, these figures provide a basis for some interesting speculation.

The frequency of transportation of insects from one country to another should be directly proportional to the adaptability of the species to carriage through the channels of commerce; and the frequency of establishment should be proportional to their adaptability to the environment in which they find themselves when they reach their destination. The frequency of successful introductions of foreign insects should, therefore, be proportional to the degree with which these two requirements are met. It is of interest to look into this question and see if the facts fit the theory.

All the important Hymenoptera in this list of agricultural pests are sawflies. These insects, because of the habit of deferred emergence from cocoons frequently found in this family, are particularly well adapted to successful transportation through plant shipments. Some species spin their cocoons on the twigs and leaves of conifers and are easily transported in this way. Others, like the pear slug, spin their cocoons in the soil, and these would seem less likely to be transported, although they might easily come in in soil surrounding balled ornamentals grown between the rows of fruit trees, as is often done in districts of intensive cultivation. After having

been brought to America in some such way as mentioned, what are the possibilities of their becoming permanently established? Arriving on living plants, or in soil containing living plants which are to be planted out, conditions would seem to be ideal for their colonization, so far as environmental factors are concerned. But the one factor which makes for their successful establishment and which transcends all others in importance is their ability to reproduce parthenogenetically. Many species of sawflies have this faculty, and most of them are thelyotokous, regularly producing female progeny only, for generation after generation, without fertilization. In fact, in many species males are entirely unknown or are very rarely encountered.

It is undoubtedly a fact that one thing which operates strongly against the successful establishment of introduced species is lack of fertilization of the females. Most insects seem to have a strongly developed instinct to disperse soon after eclosion takes place, and for this reason the chances are much against their meeting individuals of the opposite sex when they find themselves in a new environment. Thelyotokous insects are not confronted with this difficulty, since a single female can successfully establish a colony. The surprising thing is that we do not have more sawfly pests of foreign origin.

The introduced Lepidoptera present such a variety of habits which have a bearing on their successful transportation and establishment that it is difficult to assign any special reason for their apparent success in this direction. Of the twenty-three introduced species in the list three are practically cosmopolitan pests of stored products, the Indian meal moth, the Mediterranean flour moth and the Anguomois grain moth. It is not necessary to look far for the reason for their cosmopolitan distribution. The gipsy moth was brought to this country purposely but its establishment was an accident. In view of its habits it is rather surprising that there have not been more of the so-called "commercial jumps" in this species. While it generally lays its eggs on large trees they are occasionally found on nursery stock and Christmas trees and even on lumber, stone, etc. The eggs are viable for several months after deposition and when they are deposited on nursery stock there would seem to be an excellent opportunity for establishment, particularly in view of the large number of eggs in a mass and in view of the fact that the females do not fly and could not, therefore, stray far from the center of infestation and fertilization thus be inhibited. For many years the federal government has maintained a quarantine on the infested area but I believe this has not always been the case.

The browntail moth was undoubtedly introduced on nursery stock in the winter webs and has been intercepted from Europe many times since it became established. The conspicuousness of its hibernating web makes it easy for inspectors to detect it. This has probably been the factor which prevented "commercial jumps" in this country. Its gregarious habits should make it a species which could easily become established.

The codling moth, by reason of the habit of the larva of crawling into the crevices of apple boxes or into almost anything else where it finds shelter, has become almost cosmopolitan. Although its habits do not seem to have any features which make it especially adapted to establishing colonies in a new region, the frequency with which it is transported together with the difficulty of controlling its spread by quarantine methods is responsible for its wide distribution.

The peach twig-borer, *Anarsia lineatella,* does not seem to be especially well

qualified for establishment in a new region, but this failing, as in the case of the codling moth, is counterbalanced by the ease and frequency with which it is transported on account of its habit of spending the winter in the crotches of dormant nursery stock. It is also, of course, difficult to detect by inspection and must often be overlooked.

Boring moths, such as *Diatrea*, *Zeuzera pyrina*, *Pyrausta nubilalis* and *Sesia tipuliformis*, are especially well qualified for introduction, since inspection for insects of this type is impractical, and coming in on living plants used for propagation, they find conditions ideal for establishment when they reach their destination.

Among the Diptera the outstanding introduced pest is, of course, the Hessian fly, supposed to have entered this country in grain straw during revolutionary times. Of the method of gaining entrance there can be little question, since it is difficult to imagine any other means by which insects of habits similar to this fly could be successfully transported to any great distance. Most of the other Dipterous pests in the list are Phorbias, or Pegomyias, which spend the winter either as larvae or puparia in the soil. Any shipment of soil from infested districts might serve to carry these insects to new localities. The box leaf-miner is, of course, ideally situated for transportation and establishment purposes, and it is surprising that this pest has not become more wide-spread. I have known of only one infestation in California, but that was severe, showing that the pest thrives under our climatic conditions.

Coleoptera, like the Lepidoptera, are of such varying habits that it is difficult to point to anything in particular to explain their successful establishment in this country. There are many species of beetles infesting stored products, such as the Bruchids and Calandras, whose habits fit them so well for transportation and establishment that they have become cosmopolitan in distribution.

The grape root-worm, *Adoxus obscurus,* may be circumpolar, but if not it was undoubtedly introduced in soil. This beetle, like the sawflies, is thelyotokous, female progeny being produced parthenogenetically, the males being extremely rare. The grape root-worm has become widely distributed on both the Eurasian and North American continents, probably as a result of this method of reproduction.

The introduction of the alfalfa weevil is rather difficult to account for, since it seems to have no habits which fit it particularly well either for transportation or for establishment. The adult weevils crawl into hay, straw or rubbish for hibernation, and it may have entered this country in that manner. The adult female beetles are fertile when they go into winter quarters and the importation of a few hibernating adults, if they escaped into an alfalfa field, might be sufficient to establish a colony. Once established in this country it is not difficult to account for its spread, since in California as many as eighty-two live adult weevils have been taken from a single camp outfit, the owners of which spent the night in the infested region of Reno, Nevada.

Scolytus rugulosus was undoubtedly introduced in nursery stock, and the sweet potato weevil in sweet potato tubers.

It is interesting to note that we have received from foreign countries practically no large wood-boring beetles of the families *Cerambycidae* and *Buprestidae*. The habits of these beetles would seem to fit them particularly well for transportation on nursery stock. Their failure to become established may be attributed to the fact that they occur in nursery stock only in small numbers, generally one to a tree, and the sexes are unlikely to emerge simultaneously. An exception

to this is *Agrilus sinuatus*, established in eastern United States.

In the order Hemiptera we find the insects which, above all others, are equipped for introduction and establishment in new regions. I believe it is safe to say that there are more cosmopolitan insects among the Coccidae and Aleyrodidae than in any other group of similar size. The reason for this is sufficiently plain. By their mode of life, firmly fixed as they are to their host plants, which as nursery stock or ornamentals for propagation purposes find wide commercial distribution throughout the world, they are better fitted for transportation than any other group. In addition to this many of them are thelyotokous, and thus a single female, finding herself on the same host plant upon which she developed in her native land, is able to establish a successful colony. We should expect this admirable adaptability to both transportation and establishment to have just the effect that it has in fact had. Inspection is not a safeguard against these insects since, particularly in the younger stages, they may secrete themselves under bark or bud scales. The Aphididae are almost equally well adapted to transportation, for, while they are not firmly fixed to their host plant like the scales, most of them deposit a tough-shelled hibernating egg well qualified to carry the species long distances under adverse conditions. Once arriving at their destination they are quite as well fitted for establishment as the Coccidae. The overwintering eggs produce a female which gives birth to living young without fertilization, and these do the same for generation after generation. It is surprising that more species of Aphididae are not recognized as cosmopolitan, and future studies by taxonomists will undoubtedly show that more of our aphid pests are of foreign origin than the records now indicate. Aside from these three families, only a relatively small proportion of the hemipterous pests in the list are introduced species, these being the pear Psylla and the tarnished plant bug, both of which probably entered the country as overwintering adults.

The Thysanoptera hibernate both as adults in sheltered places and as nymphs in the soil, and may easily be transported under either condition. *Heliothrips fasciatus* is often found hibernating in the navel ends of oranges, although it does not attack this fruit. It is supposedly native but other species have similar habits. The pear thrips spends the winter in the soil in great numbers in infested orchards and could easily have been brought in in this way. So far as establishment is concerned, several species reproduce parthenogenetically. This is notably true of the green-house thrips, the male of which has never been discovered. This is apparently not true, however, of two of our most serious introduced species, the onion thrips and the pear thrips.

Among the Orthoptera I have not come across any records of the introduction of foreign species which have become agricultural pests, although they may exist. *A priori* it may be assumed that their transportation through commercial exchange would be extremely unlikely. Grasshoppers usually deposit their eggs in the soil, it is true, but as a general rule they prefer either sod land or extremely hard soil, such as one would be unlikely to find in European nurseries and which would hardly be found in shipments of balled nursery stock. Tree crickets and katydids deposit their eggs in twigs and on leaves, and these are better equipped for transportation to a new region than are the grasshoppers. It is unlikely that any of these insects reproduce parthenogenetically, and therefore they are not particularly well adapted to the establishment of new colonies.

A consideration of the entire matter of transportation to and establishment on the North American continent of foreign insects must, it seems to the writer, lead to the conclusion that it is entirely a question of the biological fitness of a species; its ability to fulfil to a high degree the requirements for successful transportation and establishment in a new region. Those groups which are best fitted for transportation and establishment, such as the scale insects, are seen to have the greatest number of cosmopolitan species in proportion to number of species in existence, and those which are least fitted for these purposes, such as the Orthoptera, have the lowest numbers of cosmopolites.

There has been a tendency in the past on the part of biologists to attribute the establishment of foreign species to some unknown factor, to some deep, fundamental principle which remained obscure. There seems to be no reason why this feeling should apply to insects since there is abundant evidence to show that the particular hemisphere or particular coast, east or west, on which the insect originated has nothing to do with its establishment in North America. Neither does there seem to be any good reason for making a mystery out of the fact that the general tendency of dispersal seems to be from east to west, as from Europe to America. This could scarcely be otherwise when we consider the nature of the commercial intercourse. There is no doubt but that many more species have been introduced from Europe to America than from America to Europe. The reason for this seems plain enough, if we examine the statistics with reference to exchange of nursery stock between the two regions. I have been able to obtain figures for only one year, 1921, as given by the U. S. Department of Commerce. These indicate that during that year nursery stock was exported to the value of $352,000 and was imported to the value of $5,221,000, the ratio of exports to imports being as 1 to 14+. If we could obtain figures on the number of plants rather than the value there would be a far greater discrepancy, since European shipments include large numbers of seedlings of relatively small value, which are not grown in this country because of high labor costs. I believe that all entomologists agree that the importation of nursery stock is the most prolific source of new pests and that this great preponderance of imports over exports explains why we have received more pests from Europe than Europe has received from us. We need not look further than this for justification of the Federal Horticulture Board's quarantine No. 37.

The number of instances of successful transportation as compared to successful establishment must be very great. Undoubtedly such insects as the gipsy moth, the browntail moth, many of the boring insects and even the Mediterranean fruit fly have been brought to our shores many times. Of the two former and of many others of our foreign pests only a single instance of establishment from foreign sources is known. This is probably due to infertility of the females and to failure to land when and where environmental conditions are suitable for their propagation. It is only by a fortunate (from the insect's standpoint) combination of circumstances, which happens only rarely, that a foreign pest becomes established in a new habitat. It would seem, then, that if we are able to shut off the major portion of the opportunities of transportation of foreign insects to our shores we should be able to prevent their establishment almost indefinitely.

The shutting out of foreign nursery stock in view of what seems to be incontrovertible evidence of its responsibility for the establishment of most of our foreign pests in America is one of the

greatest steps which has ever been taken in preventive entomology. In a country like this, with such varied climatic conditions and a resourceful people, there seems to be no good reason why practically everything needed in the way of plants for propagation should not be produced somewhere on the North American continent, and thus reduce almost entirely the risk of additional introductions. To one accustomed to seeing thousands of Eucalyptus trees in California without a single insect attacking them, the knowledge that there are numerous serious pests of these trees in Australia is cause for congratulation that they were introduced in the seed stage rather than as nursery stock. It is a wonderful illustration of what quarantine can accomplish if we can do in practice that which is theoretically necessary to keep pests out.

Once a foreign pest has become established in our country, what should be the attitude of the economic entomologist? Should eradication be attempted, and if so, under what conditions? Apparently entomologists are not in entire agreement on this question. A few years ago the statement was occasionally made that once an insect became established, eradication was an impossibility. There certainly is no biological basis for such a feeling; there is no biological reason why any pest could not be eradicated, but whether or not it should be attempted must be decided only after careful consideration of the habits of the insect, the probable extent of the infestation and the economic factors, such as public support and financial backing. If, after carefully weighing these items, it appears that there is a reasonable probability of a successful outcome, it certainly would be economy in the long run to make the attempt. Entomological history is replete with instances where such opportunities presented themselves and were allowed to pass by. To the credit of the entomologists, however, it must be said that this failure can not be laid at their door. In 1894 the federal Bureau of Entomology sent an entomologist to Texas to investigate and report on a new cotton pest which had appeared along the Rio Grande. This entomologist urgently recommended, after thorough investigation, that "laws should be passed decreeing the Rio Grande border of Texas for a width of fifty miles to be a non-cotton-producing belt, compelling all persons to abandon the raising of cotton in that area, and providing for the destruction of all cotton plants (and other Malavaceae, if such exist) within the same." It is unnecessary to relate that this recommendation was not carried out. Whether or not it would have proved successful in preventing the stupendous damage later caused by the cotton boll weevil can not, of course, be determined, but so far as I know there is no biological reason why it should not have succeeded. Not long ago I read a statement from a Louisiana paper quoting a banker as saying that "at last the entomologists are beginning to realize that the cotton boll weevil is a serious pest." It was this same type of mentality that opposed the carrying out of the above recommendations of the entomologists.

In 1889 the gipsy moth, well known at that time as a serious pest in Europe, was confined to an area of one and one half miles long by one half mile in width at Medford, Massachusetts. At that time Professor Fernald recommended its extermination, and Riley and Howard, of the Bureau of Entomology, urged that "it can be entirely killed out with the expenditure of a little time and money." Support for this idea was not forthcoming, however, and since then millions and millions of dollars have been expended simply in an effort to check its spread, with no end in sight. Biologically, the eradication of an insect

of habits like the gipsy moth, which exists solely in the egg stage for many months and in which the female does not fly, should have been easily possible over such a comparatively small area. Examples of this kind might be multiplied but it is unnecessary. There are without question many cases of introduction of pests in which an eradication attempt would be inadvisable, but where for a considerable portion of the year there are no adults flying and the habits are such that the other stages are easily destroyed by thorough work and the known distribution is not too great such an attempt would be well worth while. Naturally a thorough knowledge of the habits and distribution of the pest must be had before a safe decision can be reached, but, when a careful weighing of biological and economic factors indicates that there is a reasonable probability of success, entomologists should not hesitate to urge this action. Millions of dollars have recently been spent in California in the successful eradication of the foot-and-mouth disease, and a similar campaign against newly established pests of habits favorable to eradication would be equally justifiable.

Introduced pests which have become firmly established in our fauna often present possibilities of biological control which should not be overlooked. This method, of course, has its limitations, but full advantage should be taken of any opportunity to help reestablish the balance disturbed by introduced species, thus preventing damage and delaying spread. In the case of those species for which no satisfactory method of control has been developed, parasite introduction becomes an absolute necessity.

It is obvious, then, that the duty of governments, so far as applied entomology is concerned, lies in following this program: *quarantine,* to exclude insect pests which have not yet been introduced or which are of very limited distribution; *eradication,* applied to those individual cases where an introduced pest is of very limited distribution and where a careful biological and economic study of the conditions gives reasonable hope of success; *biological control,* to reduce the population of an insect pest below the danger line or to reduce it to the point where mechanical methods give more perfect results, and finally, as an additional safeguard, to develop the *mechanical* and *cultural methods* of control to the highest possible degree of perfection.

There is nothing which is more indicative of the progress of the profession of applied entomology than the increased attention which is being paid to preventive methods. Quarantine, eradication and biological control are coming to the forefront, thus paralleling, in a way, the development in medicine, the greatest of all biological professions. Preventive entomology requires not only advanced technical skill and a knowledge of insect ecology, but it requires also a high grade of organizational ability. Fortunately, because of continual contact with economic problems, both these characteristics are to be found in an increasing degree in the membership of the entomological profession.

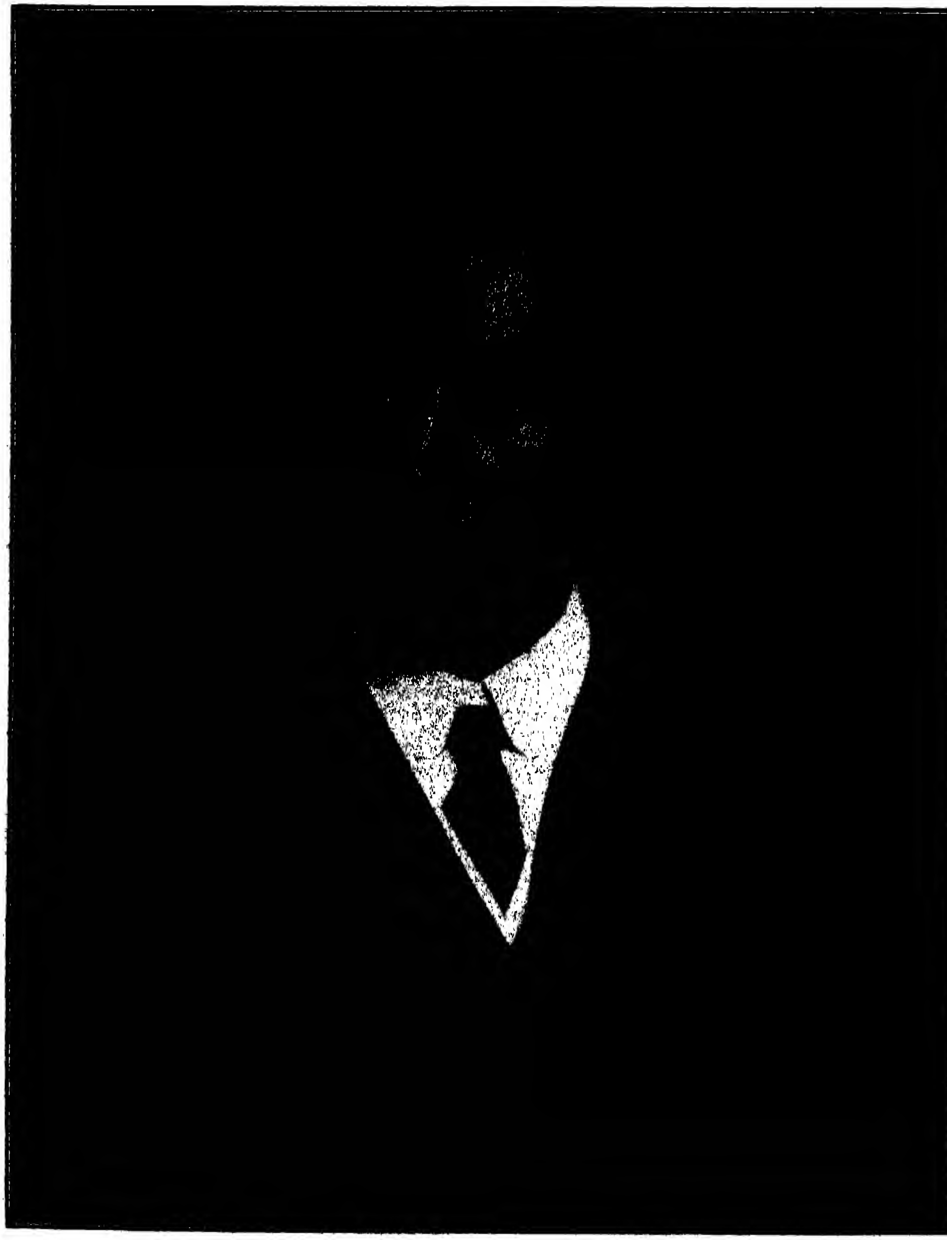
THE PROGRESS OF SCIENCE

THE BRITISH ASSOCIATION IN SOUTH AFRICA

THE British Association for the Advancement of Science normally holds its annual meetings in successive centers in the United Kingdom. Its meeting-places are not chosen in rotation, but depend upon invitation, from the municipal councils, universities and other appropriate authorities; and such invitations during the ninety-eight years of the association's existence have never been lacking. And from time to time the call comes from one of the dominions, and the association, in answering it, fulfills a duty peculiar to itself. As in the course of years world-travel has become easier and quicker, it has come about that many congresses, national and international, have been organized in the dominions of the British Empire to meet the interests of special branches of science and industry, and to bring together from all over the world experts in some one particular sphere of interest. But the British Association brings all departments of science within its scope and affords a unique opportunity for intercommunication between them. Meetings overseas, moreover, allow scientific workers in every field, from the homeland or from foreign countries, to meet their colleagues in the dominions. America has had experience of this through the meetings of the association in Montreal (1884), Winnipeg (1909) and Toronto (1897 and 1924). At the last Toronto meeting the British visitors welcomed a large number of American fellow-workers who crossed the international boundary to join them. At earlier Canadian meetings the same thing had happened; and many of the British men of science took the opportunity to visit their colleagues in the United States, to enjoy their hospitality and to make personal acquaintance with the seats of learning and the natural scientific interests of the country. The famous Baltimore lectures by Sir William Thomson, afterwards Lord Kelvin, given at the instance of the authorities of the Johns Hopkins University, followed after the Montreal meeting of the association in 1884, at which Rayleigh was president. Moreover, Thomson and other British representatives were enabled to be present at the meeting of the American Association in Philadelphia; and 1884 has been since described as "a wonder-year of scientific conference between physicists of the old world and the new." And this is but one example.

When the association met in South Africa in 1905, 380 visiting members made the journey overseas. The main meetings were held at Cape Town and Johannesburg, and official visits were also paid to Durban, Pietermaritzburg, Pretoria, Bloemfontein, Kimberley, Bulawayo and other centers, and also to the Victoria Falls, where the president of the association, Professor (afterwards Sir) George Darwin, opened the railway bridge.

The meeting this year will follow similar lines. It begins in Cape Town on July 22, the opening function being made the occasion for an address by Mr. J. H. Hofmeyr, administrator of the Transvaal and president of the South African Association for the Advancement of Science, the inviting body, which will merge its annual meeting with that of the British Association. The visiting party proceeds on July 28–29 by way of Kimberley, where it will be entertained by the De Beers Consolidated Mines Company, to Johannesburg. Here, on July 31, Sir Thomas Holland delivers his presidential address. Special opportunities for coop-



SIR THOMAS HOLLAND

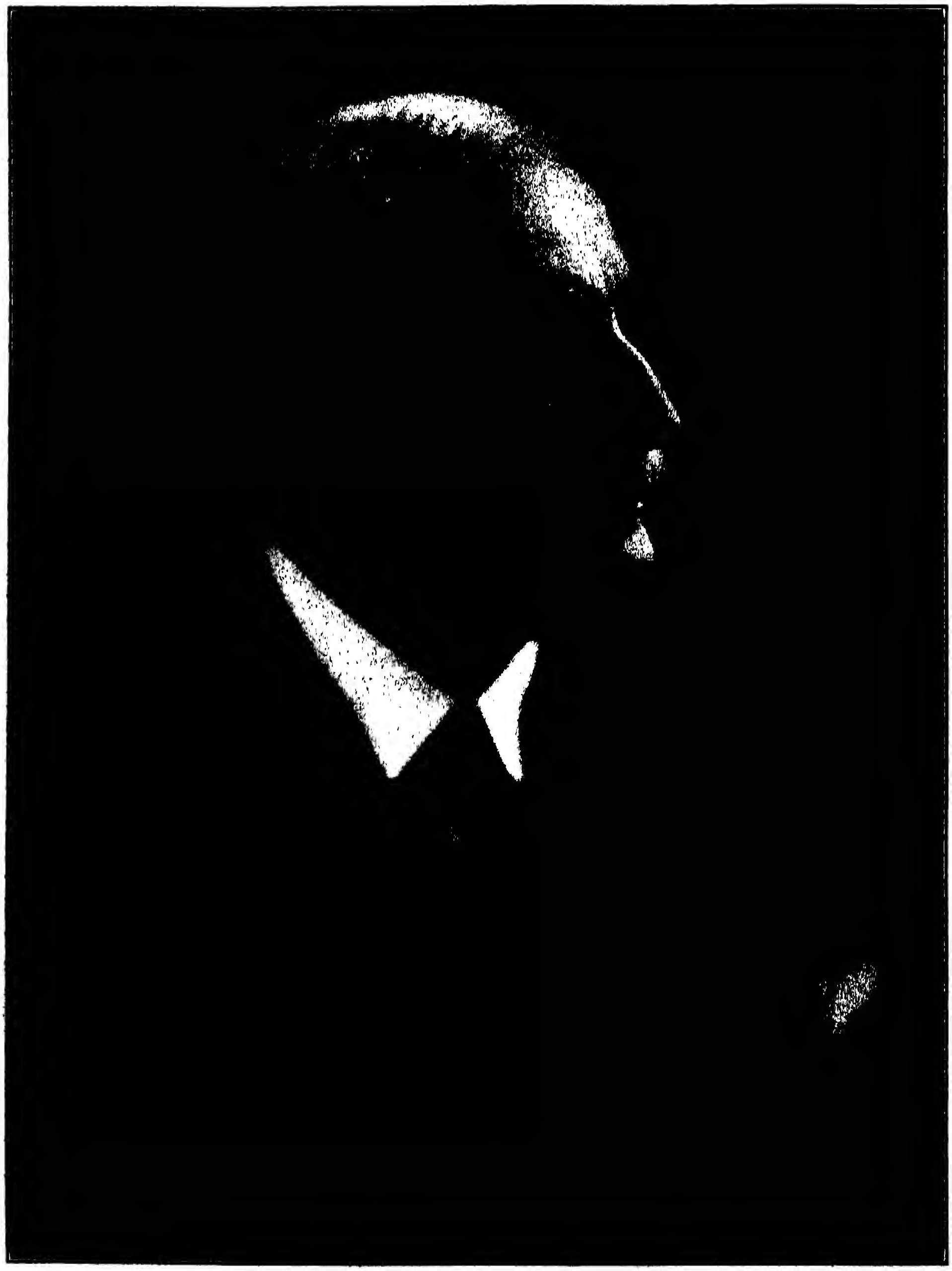
PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. RECTOR OF THE IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, LONDON, AND PREVIOUSLY PROFESSOR OF GEOLOGY AND MINERALOGY IN THE UNIVERSITY OF MANCHESTER.

eration will be afforded between the association and the International Geological Congress in Pretoria and a Pan-African and Departmental Agricultural conferences in the same city. All the sections of the association will hold meetings in Cape Town and in Johannesburg, and the various scientific interests of these cities and their neighborhoods will be explored. After the meetings in Johannesburg and Pretoria, most visiting members will take advantage of one or other of a series of tours which are offered by the travel and tourist department of the South African Railways. These will give occasion for visits to several of the other important cities of the Union, such as Durban, Bloemfontein and Pietermaritzburg, and it is likely that lectures will be given in these places and elsewhere by distinguished scientific visitors. Parties also are expected to proceed to Lourenço Marques in Portuguese Territory, to Rhodesia and the Victoria Falls, with calls at Bulawayo and the antiquarian remains at Zimbabwe. These last are to be reinvestigated in advance, and an important report upon them is expected at the meeting. Lastly a selected party will visit the colony of Kenya by invitation of its government. Arrangements so comprehensive can not fail to leave a permanent mark upon the development of scientific research in South and East Africa, and (speaking more generally) to alleviate that sense of remoteness and aloofness which even yet, in the minds of so many people, attaches to southern Africa.

FURTHER PROGRESS IN CRYSTAL ANALYSIS

In an address before the Royal Institution of Great Britain, Sir William Bragg, Fullerian professor of chemistry at the institution, explained that alloys have played a great part in the history of mankind. The qualities of pure metals are rarely desirable, but the properties of alloys cover a far wider range, within which can be found every variety of usefulness. Pure copper is too soft for most purposes, but when varying quantities of tin are introduced the bronzes so formed have many applications. At one stage of human development bronze was all-important. It is still largely used. The copper coinage is only slightly alloyed; the useful "gun-metal" contains a larger quantity of tin; bell-metal contains more, and speculum or mirror-metal more still. Small quantities of other substances, especially zinc, are often inserted into bronzes; and the influence of minute quantities of such foreign substances is remarkable. Since many substances can be used in making alloys, two or more at a time, and since even minute quantities of a component often change the properties entirely, it will readily be understood that the possible variations are almost infinite. Among these metallurgists seek for those which can be put to practical use. Great advances have been made in recent years, and such terms as chrome steel, manganese steel, duralumin and the like, have become common.

The reasons for this variety are most obscure, and great interest attaches to any method which can help to bring order and understanding into the complexity. The X-rays have come to give assistance of a novel kind. They reveal the modes in which the atoms are arranged in solid substances, provided that any regularity of arrangement exists, and in general this is the case. It turns out that the atoms in the different phases of a mixture are put together according to different patterns, and the properties of the substances are obviously connected with the pattern. In pure copper the atoms are piled together in close packing, like spherical shot; each sphere then touches twelve neighbors. When a small number of zinc atoms are added they distribute themselves at ran-



—Photograph by Frank Moore.
Courtesy of the American Institute of Electrical Engineers

CHARLES FRANCIS BRUSH

DISTINGUISHED FOR HIS WORK IN THE DEVELOPMENT OF ELECTRIC ARC LIGHTING, WHO DIED AT HIS HOME IN CLEVELAND, ON JUNE 15, AT THE AGE OF EIGHTY YEARS.

dom amongst the copper atoms without disarranging the pattern very much. But there is a limit to this addition. If too much zinc is put in a new pattern is formed, in which each atom now has only eight neighbors. Next comes a remarkable change as more zinc still is put with the copper. A very complicated pattern is formed of which the unit is twenty-seven times as large as in the preceding case, and there are fifty-two atoms in it. This alloy is very hard and brittle. Curiously enough there is an alloy of copper with aluminium, and again of copper with tin, in which the same properties are exhibited, the same pattern is found, and the same number of atoms in the pattern. Moreover, what is still more interesting is that there is the same number of free electrons. The free electrons are those which a metal can shed comparatively easily: a zinc atom can shed two, an aluminium atom three and a tin atom four. These curious alloys are composed of five atoms of copper to eight of zinc, nine of copper to four of aluminium, and the third, very approximately, in the ratio of thirty-one of copper to eight of tin. In each case there are thirteen atoms to twenty-one electrons.

Professor Bragg says that these new results, which are most interesting from all points of view, are due mainly to the work of Owen and Preston, Bradley, and Bernal in England, Westgren and Phragmen in Sweden. They open up new ideas of the conditions in the alloy. They suggest that we ought not merely to think of an alloy as a mixture of atoms, but in some cases at least as a mixture of electrons with atoms, the latter having considerable latitude as to nature. Somewhat similar conclusions have been reached in regard to the silicates composing by far the major part of the earth's crust.

In a different direction an important step forward has been made in Mrs. Lonsdale's (Miss Yardley) determination of the disposition of the atoms in the organic compound hexamethyl benzene. The application of the X-ray methods to organic structures has always been very tempting, because the properties of the organic molecule depend so remarkably on the mutual arrangement of the atoms of which it is composed. This has of course been long known, and it has been found possible to arrive at some knowledge of the particular designs by studies of the chemical reactions peculiar to them. But the X-rays may be expected in the end to furnish quantitative, as against qualitative, details of the molecular structure, and to give the relative positions of the atoms in space. The long chain compounds, which constitute a very important section of the organic substances, have already been attacked with success, but the other important section, consisting of substances founded on the benzene ring, have not hitherto proved so amenable. They are more complicated, and their analysis is more difficult. If any one of them can be worked out in detail the whole problem will be simplified. It appears that Mrs. Lonsdale's solution in the case of hexamethyl benzene has actually provided this initial success. The molecule consists of the hexagonal benzene ring of carbon atoms, to each of which is attached a methyl group (CH_3). The unit of pattern contains only one molecule. It is triclinic, that is to say, there are no planes or axes of symmetry; there is, however, a center of symmetry. As there is only one molecule in the unit cell, this center is found in the molecule itself, the only symmetry which it possesses. In certain ways the cell very nearly possesses other symmetries, and by a skilful use of these approximations as measured by the curious effect which they have on the relative intensities of reflection by different sets of planes within the crystal, Mrs. Lonsdale has been able to place every carbon atom in the molecule.

—*Bachrach*

JOHN WILLIAM HARSHBERGER

INSTRUCTOR AND PROFESSOR OF BOTANY IN THE UNIVERSITY OF PENNSYLVANIA FROM 1892 UNTIL HIS RECENT DEATH. AN ARTICLE BY PROFESSOR HARSHBERGER ON FACILITIES FOR BOTANICAL INVESTIGATION IN SOUTH AMERICA WILL BE FOUND IN THE PRESENT ISSUE OF THE SCIENTIFIC MONTHLY.

COLUMBIA UNIVERSITY AND THE ELGIN BOTANICAL GARDENS

LAND that was the site of America's first botanic gardens, the Elgin Botanical Gardens, erected in 1804 by Professor David Hosack, a man considered a little queer and his project listed in those days as a folly as many early scientific efforts were considered, will in 1938 be producing an annual income of approximately $3,000,000 to Columbia University. For the use of this income the university already has planned.

This income will result from the lease to John D. Rockefeller, Jr., of property owned by the university between 48th and 51st Streets and extending from Fifth Avenue to within 100 feet of Sixth Avenue. The contract, dating from last October, provides for a lease of twenty-four years, and three renewals of twenty-one years each. The annual income eventually will be approximately $3,000,000 as compared to about $300,000 which the university has been receiving from 203 separate leaseholds. It is proposed to use part of this property as a site for a new opera house and the remainder for a modern shopping center. The details of this project remain to be worked out.

Although the lease with Rockefeller dates from last October, Columbia University will not realize the full income for a period of years owing to the fact that it has not yet been able to acquire all of the previous leaseholds, some of which have until 1938 to run.

In acquiring leaseholds that had not expired, the university has already borrowed $6,000,000 which must be repaid out of the income. Concerning the disposition of the remainder of the income, President Nicholas Murray Butler made the following statement at the time of the announcement of the Rockefeller lease: "In anticipation of an increased income from this property at about this time, the trustees of the university had already incurred debts and budget obligations which would absorb all the increased income for some time to come. The greatly increased salary schedule for all academic officers, adopted in April last (1928), the much greater cost of maintaining the work of the medical school at the new medical center, and repayment of amounts borrowed to construct the costly research laboratories for the physical and chemical sciences

which were completed last year will require the use of the new income for several years."

The recently completed laboratory buildings to which Dr. Butler referred are the new fourteen-story physics building which houses the departments of physics, astronomy and optometry, and the eleven-story annex to Havemeyer Hall which provides additional laboratory facilities for the department of chemistry and the department of chemical engineering. Now under construction is an eleven-story addition to Schermerhorn Hall to be erected at a cost of $1,000,000. This new addition will house additional facilities for zoological and botanical research.

In addition to these buildings at Morningside Heights, Columbia is a partner in the Medical Center project which is valued at $21,000,000 and which includes the schools of medicine and of dental and oral surgery. Large research plans were instituted in both of these schools last fall when they moved into their new quarters.

The plot of ground which is to provide an income to aid in the maintenance of research plans at Columbia was the location of the Elgin Botanical Gardens from 1804 to 1810. Professor David Hosack, one time a student at Columbia, later professor of botany there and then professor of materia medica at the College of Physicians and Surgeons, established the garden and within two years had 2,000 rare botanical specimens growing there. In 1810 he was forced to sell the plot to the state because of inability to gain either college or state aid for the gardens.

The land leased to Rockefeller is part of the tract which Columbia acquired in 1814, at a time when other New York colleges benefited by cash gifts from state lotteries. The Reverend John M. Mason, at that time president of Columbia, was roundly criticized for accepting the land in lieu of a cash gift, because, his critics said, the land was worth nearer $6,000 than the $80,000 at which the state then valued it. It was not until the 1850's that the university began to realize the value of the land. Prior to that time, it had failed to gain a fair return on leases, and had been forced to borrow large sums to meet the cost of street improvements.

About this time, some of the trustees realized the possibilities of the land, and it was laid out in city lots. Sixteen of these lots were disposed of to the Dutch Reformed Church for $80,000 in 1857, and in 1904 the part of the site lying between 47th and 48th Streets was sold for $3,000,000. The remainder of the property has steadily grown in value and has produced a large income from ground leases.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1929

ARCHEOLOGICAL EVIDENCES OF THE ANTIQUITY OF DISEASE IN SOUTH AMERICA

By Professor ROY L. MOODIE
SANTA MONICA, CALIFORNIA

INTRODUCTION

ALTHOUGH the territory now included within Peru has furnished the majority of the evidences of the ills and accidents to which the ancient South Americans were liable, yet there are in other parts of the continent traces of prehistoric diseases.[1] These scant evidences have been reviewed[2] elsewhere and we may restrict our attention in this place to the more abundant evidences presented by archeological discoveries in the territory in and around Peru.[3,4,5]

The prehistory of the Peruvian area is one of fascinating interest.[6] In this region people of diverse cultures have lived for thousands of years.[7,8] Dynas-

1 R. Verneau. 1903. "Les anciens Patagons." Contribution a l'étude des races précolombiennes de l'Amérique du Sud. Monaco, pp. 1–342, figs. 1–8, pls. 1–xv. Lesions pathologiques, pl. x.

2 Roy L. Moodie. 1923. "Paleopathology." Urbana, pp. 1–567, plates i–cxvii, 49 text-figs. A review of the evidences of disease and injury from early geological time down to about A. D. 600. Chapter XV reviews the evidences from South America.

3 Frank Albert Burton. 1927. "Some Considerations on Prehistoric Aural, Nasal, Sinus Pathology and Surgery." El Palacio Press, Santa Fé, pp. 1–38, figs. 1–17.

This important study is based on the collection of pre-Columbian Peruvian material at the San Diego Museum, assembled by Dr. Aleš Hrdlička. The author, a practicing surgeon of San Diego, discusses diseases and surgical operations on the ear, eye, nose and mouth, illustrating his discussion by good, enlarged photographs of the prehistoric material.

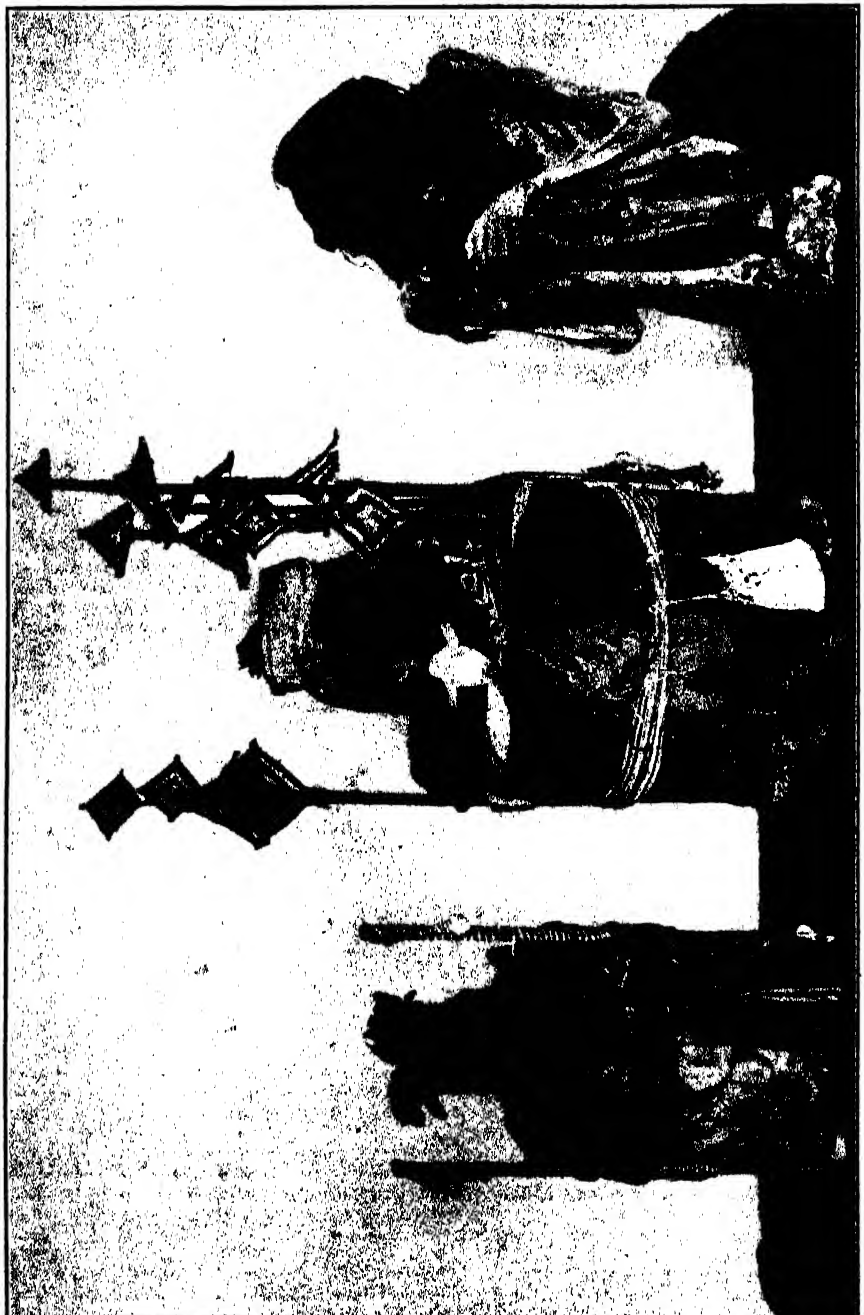
4 Field Museum of Natural History has an extensive program of study under way, dealing with the prehistoric mummies in its collections. A part of this work is the interpretation of evidences of disease from numerous, large-sized Röntgenograms of the unopened mummy packs, which has been undertaken by the author.

5 R. L. Moodie. 1926. "Tumors of the Head among Pre-Columbian Peruvians," *Annals of Medical History*, 8: 394–412, 15 figures. 1927. "Injuries to the Head among Pre-Columbian Peruvians," pp. 298–328, figures 1–22.

6 W. Reiss and A. Stübel. 1880–1887. "The Necropolis of Ancon in Peru." A contribution to our knowledge of the culture and industries of the Empire of the Incas, being the results of excavations made on the spot. Translated by Professor A. H. Keane. Three large, sumptuous, folio volumes, illustrated by colored lithographic plates. The most extensive account of ancient mummies which has appeared.

7 A. L. Kroeber and his associates have published, 1924–27, important discussions of the Max Uhle collections of prehistoric potteries, furnishing for the first time a reliable basis for a chronology of pre-Columbian events. Seven contributions have been issued as University of California Publications in American Archeology and Ethnology.

8 G. G. MacCurdy. 1923. "Human Skeletal Remains from the Highlands of Peru," *American Journal of Physical Anthropology*, 6, no. 3, pp. 218–329, pls. 1–xlix. Papers 8 and 10 deal



—*Courtesy of the American Museum of Natural History*

FIG. 1. THREE PREHISTORIC PERUVIAN MUMMIES FROM ANCIENT CEMETERIES

—*Courtesy of the American Museum of Natural History*

FIG. 2. AN ELABORATELY EQUIPPED, COMPLETE MUMMY-PACK

WITH FALSE HEAD, FROM TRUJILLO, NEAR RUINS OF CHAN-CHAN, PERU. THE FOLDED MUMMY IS WITHIN THE LOWER PART OF PACKAGE.

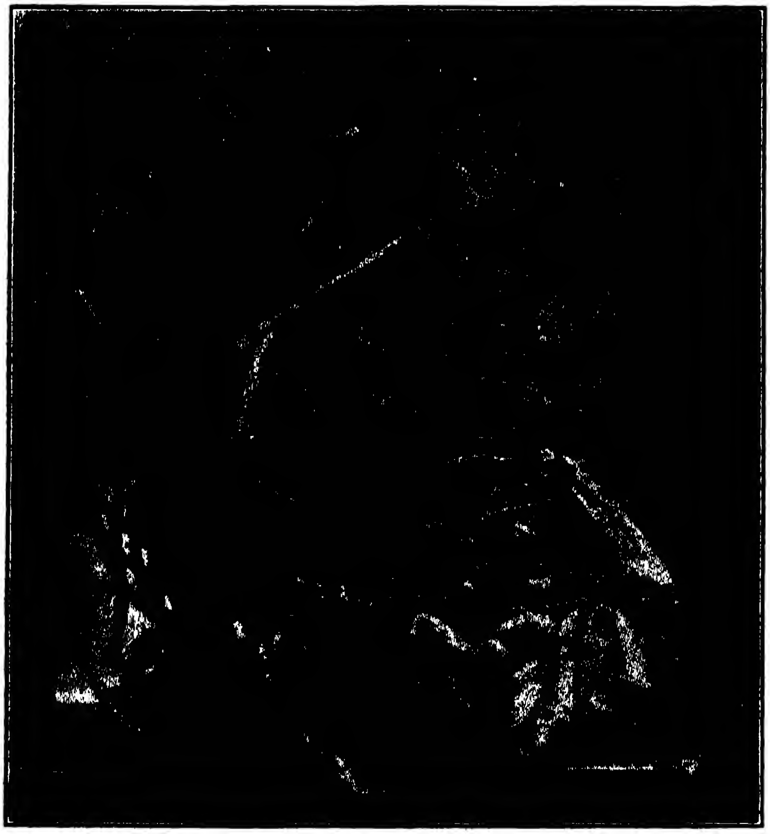


FIG. 3. MUMMY-PACK

FROM THE FAMOUS NECROPOLIS AT ANCON, PERU, WHICH HAS YIELDED GREAT NUMBERS OF DIVERSIFIED SPECIMENS. THIS ONE, WRAPPED IN CLOTH AND SKINS, CARELESSLY TIED IN A LOOSE, IRREGULAR NETWORK OF HEAVY CORD, IS AN INTERESTING EXAMPLE OF COMMON TYPE OF PACK. ON THE LEFT ARE TWO REEDS WRAPPED WITH THREAD, AND THE BAG, NOW TORN, DOUBTLESS CONTAINED WEAVING MATERIALS. THIS SPECIMEN, NO. 5913, FIELD MUSEUM OF NATURAL HISTORY, IS TWENTY-THREE INCHES LONG, EIGHTEEN INCHES WIDE, WITH A DEPTH OF SIXTEEN INCHES. COLLECTED BY GEORGE A. DORSEY.

ties grew and waned centuries before recorded history, and it is the task of the prehistorian to puzzle out, from the material at hand, the details of the daily life[9, 9a] of those ancient and interesting people.

RUINS

Some of their ruins[8] are notable either in point of size or massiveness of con-

with the evidences seen on skeletal material collected in conjunction with the exploration of Machu Picchu, by Yale University. These are the best anthropological papers on pre-Columbian Peruvians within recent years.

[9] Leonard Freeman. 1924. "Surgery of the Ancient Inhabitants of the Americas," *Art and Archeology*, 18: 21–35, figs. 1–24. The author, a surgeon in Denver, presents the best general account of the subject so far published. His material was largely that preserved in the San Diego Museum.

[9a] Garcilasso de la Vega, son of an Inca princess and a Spanish father, after many years of residence in Spain, wrote largely from memory, tradition and writings of contemporaries, his "Royal Commentaries," which give helpful sidelights on the life of the ancient Andeans.

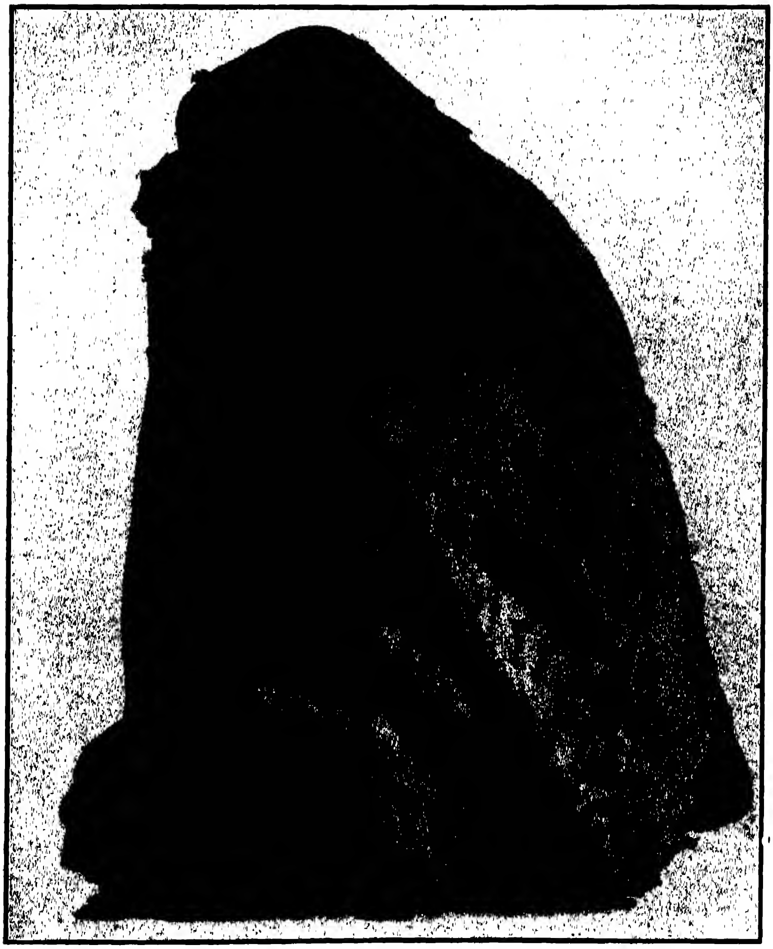


FIG. 4. PREHISTORIC MUMMY-PACK FROM ICA VALLEY, PERU
CLOTH COVERING DISINTEGRATING. MUSEUM OF ANTHROPOLOGY, UNIVERSITY OF CALIFORNIA. COLLECTED BY MAX UHLE.

struction. The city of Chan-Chan, covering eleven square miles, is thought to have had a population of hundreds of thousands. Its sixty-foot protecting wall is now reduced to mounds of earth by centuries of erosion.

Among these ruins, opened through the centuries by treasure hunters, occur the potteries, the implements, the mummies and other archeological objects on which is founded our knowledge of the antiquity of disease in this area. Vandalism[7] still goes on, in spite of legal restrictions. Mummies, wrapped and unwrapped, bones, potteries and other objects are thrown carelessly aside or broken open in the search for treasure. From this discarded material have been secured the evidences for the antiquity of disease in this part of South America.

MUMMIES

Among the archeological objects examined for this purpose the mummies

are, of course, the most important. Many of the known mummies were carefully prepared by drying[9a] and wrapped in skins or cloths and were bound, more or less neatly, with woolen cords.[6] Wallis Budge has estimated that of the millions of people who lived in Egypt while embalming was in vogue probably not more than a hundred thousand were embalmed. Mummies were expensive and only the rich could have their bodies prepared for resurrection and life eternal with Osiris. It is possible that a similar ratio obtained among the ancient Andeans. The museums of the world possess only a few hundred. A few thousand have been destroyed by treasure hunters, and an untold number remain buried. The vast majority of the population is still to be accounted for.

Mummies which were thrown aside by vandals soon lost their coverings of cloth and dry skin, leaving their bones to exhibit such evidences of disease[5] as may have made permanent alterations in the structure of the bones. Unwrapped mummy-packs may be examined by means of the X-ray;[4] which reveals most of the diseased alterations of the skeleton, and some of the soft parts. Scores of prehistoric mummy-packs (Fig. 20) have been thus examined, and will soon be described.

The details of the preparation of the dead for burial both in the Andean highlands and along the coast are still to be determined. Sun drying, both in the mountains and along the coast, seems to have been most prevalent and we do not know that the abdomen was ever opened, although their skilled surgeons had no hesitancy in opening the head.[9,10]

Some of the mummies discovered in the necropolis at Ancon[6] are wrapped in fine skins (Fig. 3) or gorgeously colored

—*Courtesy Field Museum of Natural History*

FIG. 5. MUMMY-PACK OF PLAITED STRAW

OPEN IN FRONT OF FACE. COLLECTED BY EMILIO MONTE AT CUZCO, PERU. LENGTH OF PACKAGE, THIRTY-THREE INCHES; WIDTH FOURTEEN AND ONE HALF INCHES; DEPTH FIFTEEN INCHES. (NO. 3522, FIELD MUSEUM OF NATURAL HISTORY.)

cloths, the colors bright and fresh (Fig. 1) after centuries in the sands. Often more than one body[11] is enclosed in a single pack (Fig. 7). Sometimes the false head is placed on the wrong end of

10 G. G. MacCurdy. 1918. "Surgery among Ancient Peruvians," *Art and Archæology*, pp. 381–395, illus.

11 Arthur Baessler. 1906. "Peruanische Mumien." Untersuchungen mit X-Strahlen. Taf. 1–15.

FIG. 6. PREHISTORIC INFANT MUMMIES

ARE ABUNDANT IN PERUVIAN BURIALS. THIS BABY, IN ITS ORIGINAL NATIVE-CLOTH WRAPPING, IS AN EXAMPLE OF NATURAL MUMMIFICATION. COLLECTED AT LUPO, NEAR HUAROCHIRI, PERU, BY ALEŠ HRDLIČKA. NO. 1149, SAN DIEGO MUSEUM.

—*After Baessler*

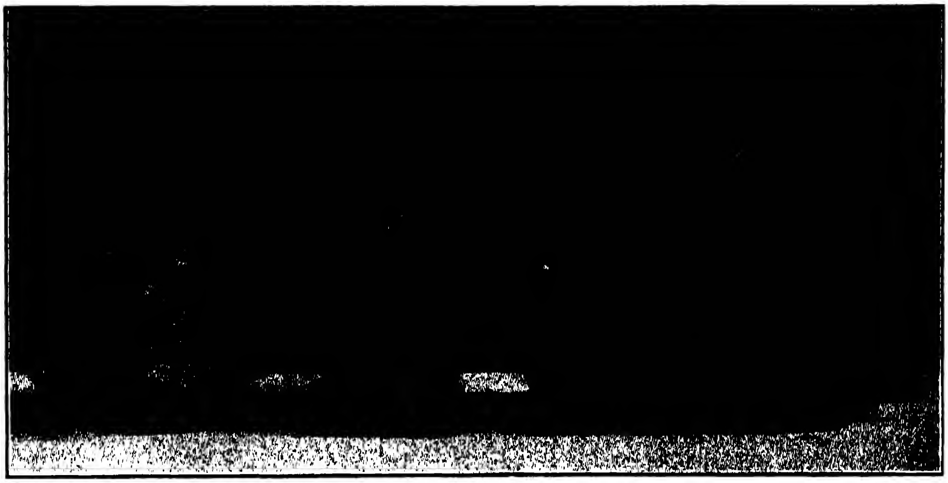
FIG. 7. A RÖNTGENOGRAM OF AN ANCIENT PERUVIAN MUMMY-PACK

SHOWING THREE BODIES WITH METAL OBJECTS NEAR THE HEADS. THE BODIES ARE ALL FOLDED AND PLACED CLOSE TOGETHER.

the package. In the mountains near Cuzco bodies were enclosed in neatly woven cases of straw or twigs (Fig. 5), or both, with an aperture for the face. Infant bodies were often carelessly wrapped in coarse cloth (Fig. 6) and tied in a negligent manner with heavy cord. Naked mummies, folded, are frequently found in a good state of preservation.

It is possible, after soaking in weak formalin solution, to identify muscles, nerves, tendons, arteries and other organs[12] in limbs of bodies many centuries old. Microscopic examination of the tissues reveals cells and their nuclei, blood corpuscles, connective and fatty tissues, and in certain areas elastic fibers.[12] The walls of an artery from the leg show evidences of disease. Often in the many Röntgenograms examined shadows of intestines, liver and spleen are seen.

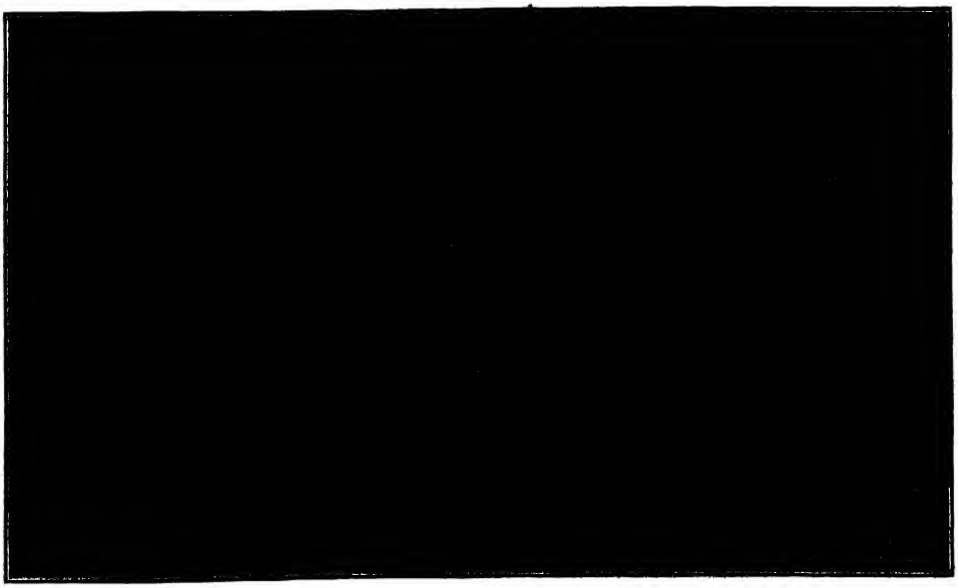
[12] H. U. Williams. 1927. "Gross and Microscopic Anatomy of Two Peruvian Mummies." *Archives of Pathology and Laboratory Medicine*, 4: 26–33.



—*Courtesy of the American Museum of Natural History*

FIG. 8. PREHISTORIC PERUVIAN POTTERY SHOWING EVIDENCES OF DISEASE

Left: VESSEL IN THE FORM OF A HUMAN HEAD, WITH EAR ORNAMENTS. THE SWELLING ON THE NOSE IS A DISEASE KNOWN AS *goundou*, KNOWN TO-DAY FROM MELANESIA AND WEST AFRICA. *Middle:* RED JAR SHOWING HUMAN FIGURE WEARING A WHITE GARMENT. UNIDENTIFIED IMPLEMENT IN HANDS. HANDLE MISSING. MOUTH SHOWING RAVAGES OF THE DISEASE *uta* CAUSED BY A PROTOZOAN PARASITE OF THE BLOOD. *Right:* JAR OF HUMAN FIGURE, LYING ON STOMACH, SHOWING DISEASED LIPS AND NOSE. HANDS CLASPED.



—*Courtesy of the American Museum of Natural History*

FIG. 9. PREHISTORIC PERUVIAN POTTERY SHOWING EVIDENCES OF DISEASE

Left: DOUBLE-SPOUTED JAR SHOWING HUMAN FIGURE WITH DISEASED MOUTH, *uta* A PHASE OF LEISHMANIASIS. VESSEL EIGHT AND THREE FOURTH INCHES HIGH. *Middle:* RED AND WHITE JAR SHOWING HUMAN FIGURE WITH DISEASE OF THE MOUTH. THE ATTITUDE IS THAT OF A HUNCHBACK. *Right:* JAR SHOWING HUMAN FIGURE WITH DISEASED MOUTH.

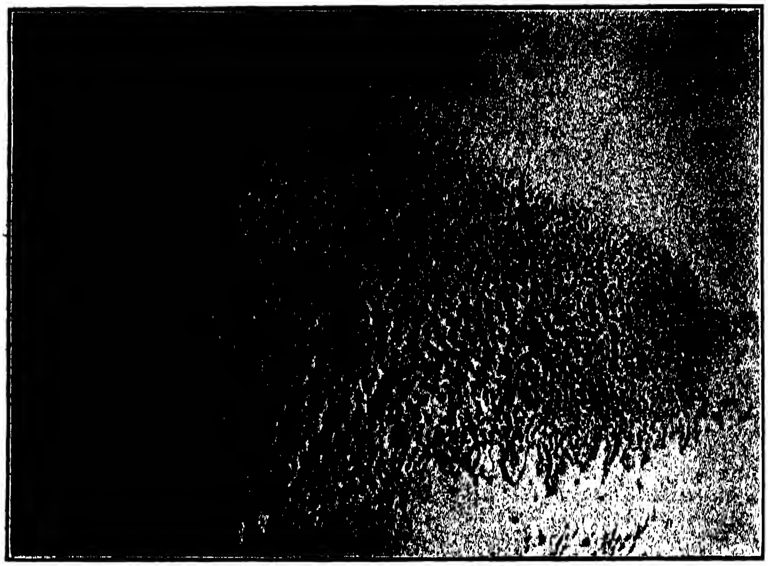


FIG. 10. THE IVORY-LIKE LUSTER OF THE SKULL

INDICATES A HEALTHFUL CONDITION OF THE BONES AT THE TIME OF DEATH. SKULL NO. 147, SAN DIEGO MUSEUM. MANY OF THE YOUTHFUL MUMMIES REVEAL THE HEALED EVIDENCES OF A NUTRITIONAL DISEASE IN CHILDHOOD.

POTTERIES

It was a wide-spread custom in prehistoric times in the Peruvian area to depict on their abundant potteries[7] many of the intimate details of the daily life of the people, their food, their fauna and flora, their portraits, pugilistic encounters and often their bodily struggles with disease. Many of these jars have a considerable antiquity. By far the most prevalent disorder represented is a loathsome affliction, by a blood parasite, of the mouth and nose—the disease being known as *uta*. It is depicted on the features of several of the potteries shown in Figs. 8 and 9. The skull shown at the bottom of Fig. 24 shows the effects of the disease, and the evenness of the wound suggests that an ancient surgeon may have excised the diseased parts with an obsidian flake in an effort to arrest the progress of the disease. A rare disease, *goundou*, otherwise unknown in the western hemisphere, is indicated by the pottery to the left in Fig. 8. Other manifestations of disease and of surgical interference are depicted on similar water jars. A direful skin disease, *Veruga peruana*, is thus shown.

PEDIATRICS

The diseases of childhood among the ancient nations must have been many and severe, if we may judge from the numerous infant mummies, but few of the diseases were such as to leave traces on the bones. Rickets, apparently, did not exist among the ancient Andeans, since no traces of its manifestations have been seen in an examination, by X-ray,[4] of numerous mummy-packs. One disease of infancy, a nutritional disorder, leaves its effects (Fig. 10) in paired lesions of the roof of the orbit or on the bones of the cranial vault. The effects of this disease, known as *Osteoporosis* or *Cribra cranii*, always remain after healing, as sieve-like patches (Fig. 10).

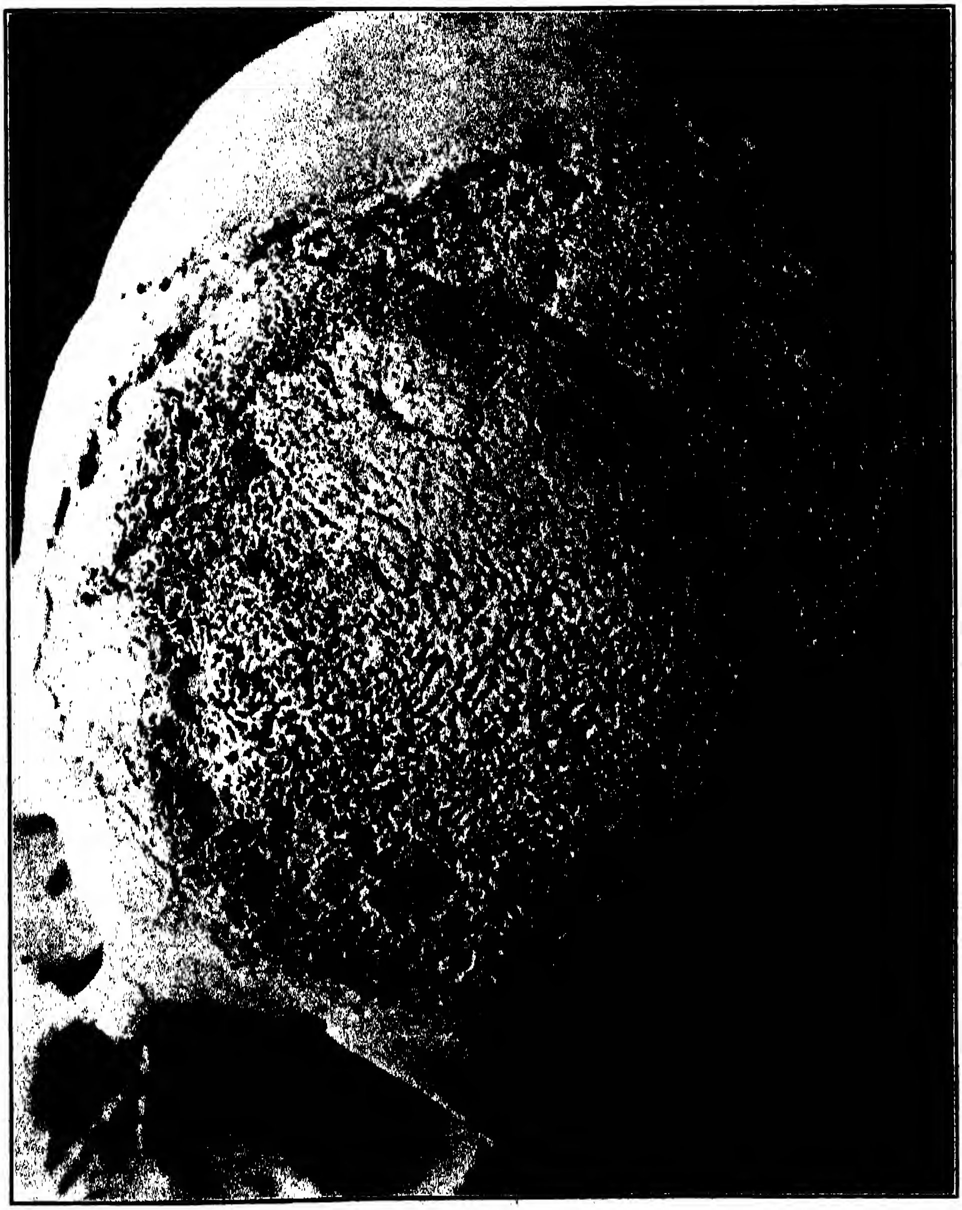
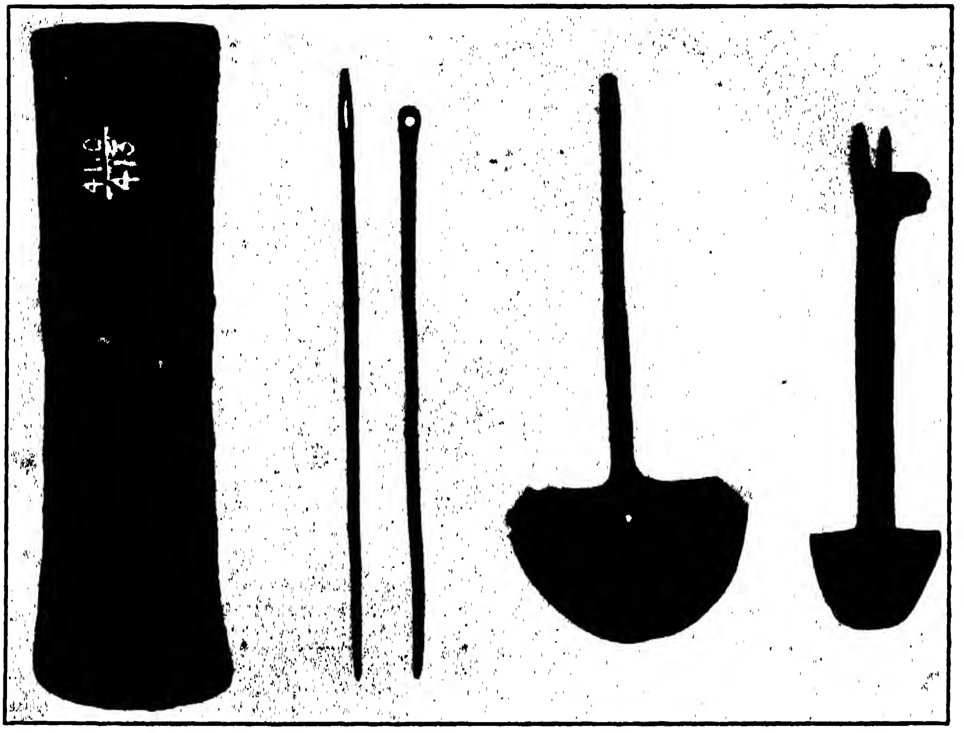


FIG. 11. AN ADULT FEMALE SKULL

PRESENTS A HUGE *Hyperostosis cranii* DUE TO THE PRESSURE OF A TUMOR OF THE BRAIN MEMBRANES. THE TUMOROUS MASS WAS OF SLOW GROWTH AND GAVE A CURIOUS, LOP-SIDED APPEARANCE TO THE HEAD. NO. 158, SAN DIEGO MUSEUM.



—*Courtesy of the American Museum of Natural History*

FIG. 12. PREHISTORIC COPPER AND BRONZE IMPLEMENTS

FROM THE ANDEAN HIGHLANDS. MODIFICATIONS OF SOME OF THESE MAY HAVE SERVED FOR SURGICAL PURPOSES. *Left to right:* A BROAD COPPER OR BRONZE BLADE; A COPPER NEEDLE FROM AN EXCAVATION NEAR LLAYAYLL, LAKE TITICACA; A COPPER NEEDLE FROM KASAPATA; A COPPER PIN OR TOPO, CERROCA, BOLIVIA; A COPPER KNIFE, SHORT BLADE, WITH HEAD OF LLAMA ON THE HANDLE.

Hydrocephalus is suggested by the shape of the skull of several ancient infant mummies.

Tumors

There are numerous instances of the presence of tumors[5] in ancient Peru, mostly of the benign type, slow-growing and often not bothersome at all. Of this type are the ivory-like osteomata of the cranial vault and on the jaw. Bony tumors, of huge growth, due to irritation from tumors in the brain membranes (Fig. 11) are sometimes found in the heads of ancient mummies. Soft tumors, of unknown type, often leave their marks of pressure atrophy on the osseous parts.

Diseases of the Teeth

The prehistoric peoples whose ills we are following suffered from a variety of dental troubles—with not a dentist to relieve them.[6] Cavity formation through caries (Figs. 15, 16), while abundant, was not nearly so prevalent as the ravages of pyorrhea. Often all teeth are lost because of this disease (Figs. 14, 17). Following upon excessive deposits of salivary calculus (tartar) pyorrhea reduced the efficiency of the teeth (Figs. 15, 16) and added bodily troubles. Abscesses (Fig. 16) were common and wide-spread, often of enormous proportions, infecting the air sinuses and spreading into the ears and mastoids.

Supernumerary and misplaced teeth (Figs. 16, 18) were not at all common.

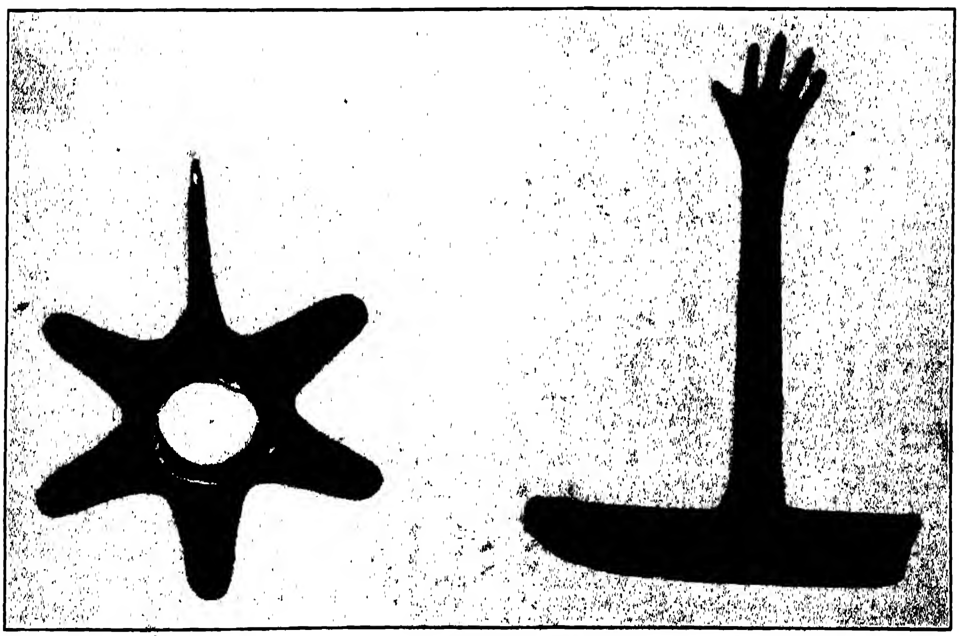
Injuries

Accidental and intentional wounds, particularly of the head,[5] were common, especially in the highlands. Some of these (Figs. 19, 23) produced by a heavy mace (Fig. 13) were immediately fatal. Others (Fig. 19), produced by sling shot, were less frequently fatal, producing depressed fractures which were relieved by trephining. Smashing blows from a heavy club are often seen to have distorted the features greatly, or to have produced a set of radiating linear fractures (Fig. 23). Broken limb bones were crudely set, or healed as best they could without interference.

Surgery

It may be that surgical interference, in prehistoric times, developed out of attempts to aid the wounded. Most of their surgical practices[3,9,10,13] were restricted to operations on the head. Of these the art of trephining was the one most commonly followed. So much has been written on prehistoric trephining that we may well be brief here. Trephinings by sawing, scraping, cutting and drilling were followed. The location and extent of the injury determined the site of the operation and the method followed. Fig. 21 shows the details of two of these methods. The upper wound, made by cutting above the orbit,[3] was made to drain a frontal sinus infection. The opening in the lower figure must have been a post-mortem practice operation, since its location on top of the

[13] R. L. Moodie, "Surgery in pre-Columbian Peru." In press. 65 figures. 1928. "The Paleopathology of Patagonia," *Annals of Medical History*, Sept.



—*Courtesy of the American Museum of Natural History*

FIG. 13. PREHISTORIC PERUVIAN INSTRUMENTS

Left: Combined copper, star-shaped mace and axe. *Right:* Knife, with human hand for handle.

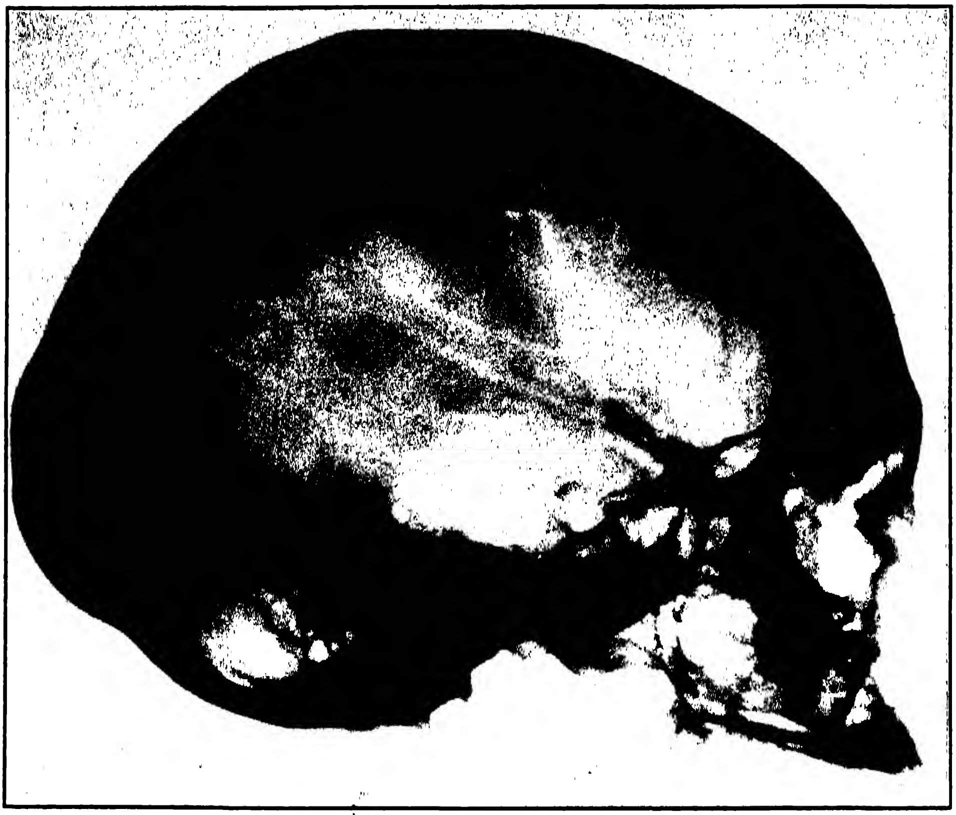


FIG. 14. RÖNTGENOGRAM OF ANCIENT PERUVIAN SKULL

OF A MALE FROM NASCA, PERU, SHOWING LOSS OF ALL TEETH THROUGH DISEASE. NO. 185, SAN DIEGO MUSEUM.

head, with an unusually thick skull, renders it improbable that there could have been an injury. A single skull shows (Fig. 22) what may have been a surgical bandage.[14] The application of heat was practiced as a counter-irritant. Excisions of diseased parts, the opening of abscesses and possibly phlebotomy were known and practiced. Primitive instruments, either of volcanic glass or copper utensils (Figs. 12, 13) served the primitive surgeon. The application of splints in fractures of long bones was unknown.

DEAFNESS

Ear troubles in prehistoric times were prevalent and are to be associated with infections from the teeth reaching the middle ear by way of the paranasal sinuses, or from the nose following the same route. Large exostosial, ivory-like growths in the outer passage interfered with or prevented hearing. The outer passage is often closed by a thickening of the walls of the meatus, as well as by osseous changes in the walls of the cochlea.

14 R. L. Moodie. 1926. "A Prehistoric Surgical Bandage from Peru," *Annals of Medical History*, 8: 69–72. Illus.

No trace of syphilis in prehistoric times has yet been found in South America.[15]

CHRONOLOGY

It is not yet possible to assign accurate dates to prehistoric events in South America. We must speak somewhat vaguely of the antiquity of civilizations in the Andean regions in terms of thousands of years, and we must date the age of potteries and mummies as that of hundreds of years ago. The prehistoric era closes at about A. D. 1530, the time of the Spanish conquest. It seems probable that there has been a continuous settlement at or near to Ancon,

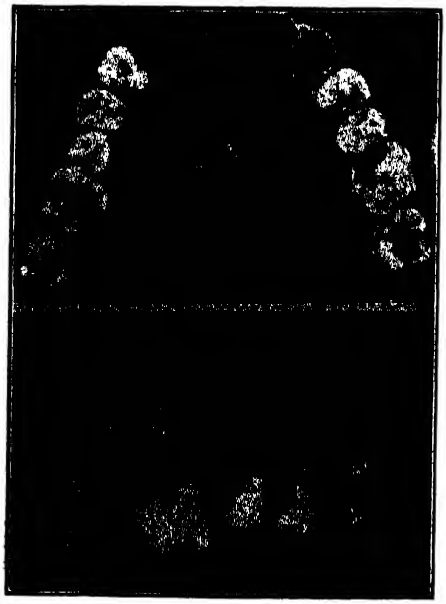


FIG. 15. DISEASES OF THE TEETH OF ANCIENT PERUVIANS

Upper: PALATE OF SKULL NO. 125, SAN DIEGO MUSEUM, FROM CINCO CERROS, PERU, SHOWING DISEASED CONDITION OF THE SOCKETS, THE BONY PALATE, AND A CARIOUS CAVITY ON THE RIGHT. *Lower:* TEETH ENCRUSTED WITH SALIVARY CALCULUS, "TARTAR," WITH EVIDENCES, IN THE EXPOSED ROOTS, OF PYORRHEA.

FIG. 16. DISEASES OF THE TEETH

Upper: POST-COLUMBIAN MALE, FROM CHAVINA, PERU. *Lower:* PYORRHEA AND CARIES HAVE BEEN ACTIVE.

FIG. 17. AN EDENTULOUS PALATE

WITH LOSS OF ALL TEETH DUE TO DISEASE.

[15] H. U. Williams. 1927. "The American Origin of Syphilis," *Archives of Dermatology and Syphilology*, 16: 683–696.

FIG. 18. RÖNTGENOGRAMS OF THE MAXILLARY REGION
OF SKULL NO. 209, SAN DIEGO MUSEUM (SEE FIG. 16), A POST-COLUMBIAN MALE FROM CHAVINA, PERU, SHOWING CONDITIONS OF TEETH AND SURROUNDING BONE. *Left:* PALATE FROM BELOW. *Right:* MAXILLA FROM RIGHT.

FIG. 19. INJURIES RESPONSIBLE FOR THE DEVELOPMENT OF "TREPHINING"
IN ANCIENT PERU. *Left:* SLING-SHOT INJURY WITH DESCENDING LINEAR FRACTURE TO ORBIT, PRODUCING A DEPRESSED FRACTURE, RELIEVED BY TREPHINING. *Right:* SKULL NO. 42, SAN DIEGO MUSEUM, FROM HUACHO, PERU, SHOWING TWO SLING-SHOT INJURIES, ABOVE, AND A HUGE, MORTAL INJURY FROM A MACE, BELOW.

—*Courtesy of the Field Museum of Natural History*

FIG. 20. RÖNTGENOGRAM OF AN INFANT MUMMY

FROM PERU, SHOWING WHAT PERFECT DETAIL THESE ANCIENT BODIES MAY POSSESS. THE EXTENDED SKELETON IS, APPARENTLY, FREE FROM DISEASE. RICKETS IS UNKNOWN IN PREHISTORIC PERU. X-RAYS DO NOT REVEAL ANY OF THE RAVAGES OF THE NUTRITIONAL DISTURBANCES.

Peru, for the past two thousand years. The chronology of Peru is being developed at Lima by Julio C. Tello by the

FIG. 21. ANCIENT PERUVIAN SURGEONS TREPHINED THE SKULL

IN SEVERAL WAYS, SAWING, SCRAPING, CUTTING, DRILLING AND BY COMBINATIONS OF THESE METHODS. *Above:* OPENING OF THE FRONTAL SINUS BY CUTTING, ABOVE THE ORBIT, IN SKULL NO. 288, SAN DIEGO MUSEUM, MALE FROM CINCO CERROS. POSSIBLY FOR RELIEF OF SINUS HEADACHE. *Below:* OPENING MADE BY SAWING WITH A ROUGH-EDGED FLAKE OF OBSIDIAN, IN SKULL NO. 308, SAN DIEGO MUSEUM, A FEMALE FROM SAN DAMIAN, PERU, NEAR CINCO CERROS.

FIG. 22. A SURGICAL BANDAGE

OF NATIVE COTTON CLOTH, ON THE HEAD OF A MUMMY FROM LOMAS, PERU, COLLECTED BY ALEŠ HRDLIČKA (NO. 658, SAN DIEGO MUSEUM). THE BANDAGE IS HELD IN PLACE BY WOOLEN CORDS, SIMILAR TO THOSE USED IN MAKING THE QUIPU.

accumulation of data and materials at the anthropological and archeological museum and at San Marcos University.

SUMMARY

The majority of the evidences of disease in South America, during prehistoric times, is obtained from pictorial representations on potteries, some of which are many centuries old, and from mummies and skeletal parts derived from mummies. Most of this material is the result of vandalism, but some scientific collecting has been done, first by Reiss and Stübel,[6] then by Max Uhle,[7] and more recently by Kroeber for Field Museum, and by Tello in Lima. Unopened mummy-packs, examined by the X-ray, have furnished a great deal of the evidences, and skeletal parts, largely derived from mummies, have shown the alterations of disease and injury.

Among the abundant infant mummies no traces of rickets are found. Other diseases of childhood are seen. Diseases of the teeth, especially pyorrhea, are common. Many injuries due to war are

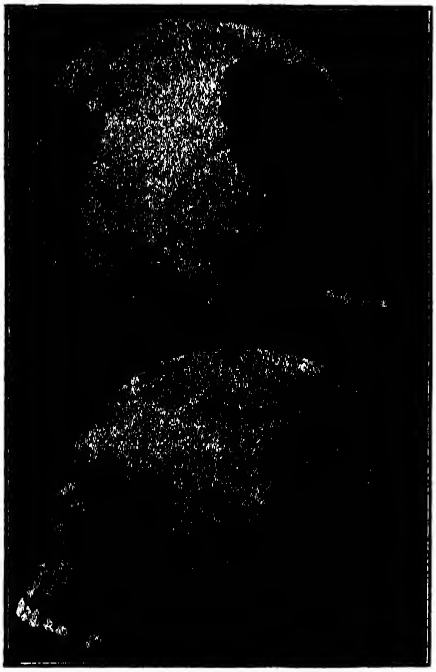


FIG. 23. TWO ANCIENT PERUVIAN SKULLS SHOWING INJURIES

Above: SKULL NO. 23, SAN DIEGO MUSEUM, FROM CINCO CERROS, SHOWING TWO HUGE MACE (?) INJURIES. *Below:* SKULL NO. 21, SAN DIEGO MUSEUM, FROM SAN DAMIAN, SHOWING EFFECTS OF A CRUSHING BLOW FROM A CLUB, WITH RADIATING FRACTURES.

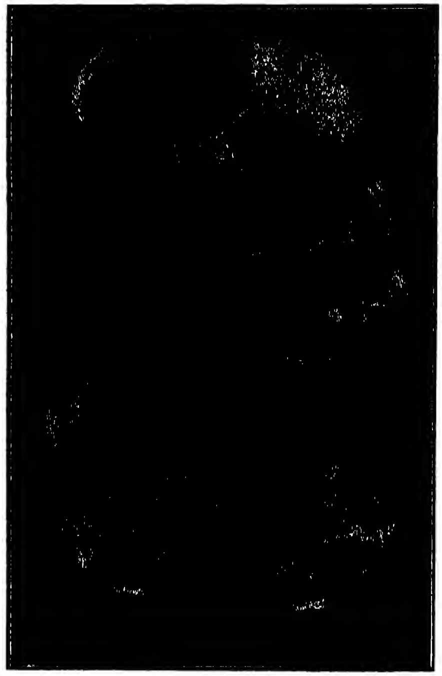


FIG. 24. ANCIENT SURGERY

Above: A LARGE TREPHINED OPENING, MADE BY STRAIGHT AND CURVED CUTTING, IN A FEMALE SKULL, NO. 257, SAN DIEGO MUSEUM, FROM CINCO CERROS, PERU. *Below:* IT LOOKS AS IF THE SURGEON HAD CUT AWAY THE PARTS DISEASED BY *uta*. SKULL NO. 86, SAN DIEGO MUSEUM, FROM CHAVINA, PERU.

found. Surgery, particularly trephining, was well established. Deafness was due to a number of causes. It will be possible to determine the diseases of the soft tissues by microscopical examination of specially prepared material.

NEW DATA ON THE ORIGIN AND SPREAD OF THE DOLLAR MARK

By Professor FLORIAN CAJORI

UNIVERSITY OF CALIFORNIA

THE examination of manuscripts in the Bancroft Library of the University of California has supplied data which lead to a fuller grasp of the, for so long, elusive knowledge of the origin and spread of that symbol which came to represent the monetary unit now dominant in the financial affairs of the world. It is well known that the United States dollar was adopted in 1785 and was modeled on the average weight of the Spanish coin then in circulation. Thomas Jefferson speaks of the dollar as "a known coin, and most familiar of all to the minds of the people."[1] The first United States dollars were coined in 1794. Jefferson does not use the dollar symbol $, or make reference to it. We shall see that its first occurrence antedates 1785.

There exist a dozen or more theories on the origin of the dollar mark. All of them are such stuff as dreams are made of. If ever the need of painstaking empirical study presents itself in the history of symbols, it is in the origin of our $. The student of chemistry and physics is not the only investigator who must subject himself to the reign of fact. When asked to submit evidence drawn from early manuscripts, the proponents of the theory that found the origin of $ in the superposition of the letters U and S (the "U. S. theory")[2] take to flight. The same is true of the advocates of the theories which ascribe the origin to the monogrammatic form[3] of I H S (often erroneously interpreted as *Jesus, Hominum Salvator*) or to H S and I I S that were abbreviations used by the Romans for a coin called sestertius,[4] or to the "pillars of Hercules" that were impressed upon the "pillar dollar"[5] of the seventeenth and eighteenth centuries, or to the figure 8 combined with a vertical bar | or with the solidus /, or with the letter P, or with the letter R, because the Spanish dollar was known as a "piece of eight"[6] or as "8 reales."

A theory which possesses great antecedent probability explains the origin of our $ from the Portuguese symbol for "thousands" which is shaped like our dollar mark. A number which we write 13,765, the Portuguese wrote 13$765. Here the $, called "cifrão," takes the place of the comma, separating hundreds from thousands. This separating is done for convenience in the reading of numbers. The "cifrão" came to be used more especially in the designation of monetary values, as in 1.043:381$000 *reis* or 1.043:381$ *milreis*. The theory supposes that the Portuguese "cifrão" was assigned the new rôle of representing the Mexican "peso" or "piastre," and to have been adopted later in the United States as our "dollar" mark. Proofs from manuscript evidence that such a change actually did take place

1 D. K. Watson, "History of American Coinage," 1899, p. 15.

2 *Notes and Queries* (Fifth Ser.), London, Vol. VI, 1876, pp. 386, 434.

3 Standard Dictionary, 1896, article, "Dollar."

4 M. Townsend, "U. S. an Index, etc.," Boston, 1890, p. 420.

5 *Notes and Queries*, London (Fifth Ser.), Vol. VII, 1877, p. 155, 317; New American Cyclopedia, Vol. VI, 1859, article, "Dollar"; W. L. Fawcett, "Gold and Debt," Chicago, 1877, p. 13.

6 M. Townsend, *op. cit.*, p. 420; *Scribner's Magazine*, 1907, 42: 515; Webster's Unabridged Dictionary, in the editions since 1864.

have never been attempted in print. The writer has examined many books and many manuscripts, but has not found the slightest evidence in support of this hypothesis. Moreover, Americans who are known to have used the dollar mark in the eighteenth century were not in contact with the Portuguese. There were no Portuguese settlements in North America. Portuguese silver money coined in Brazil did not in the eighteenth century circulate in the American colonies, nor, so far as we are able to ascertain, in the West Indies or the Gulf coast. There is no evidence that the name "milreis" or the name "cifrão" ever came to be synonymous with "dollar," or "peso." The cifrão hypothesis must therefore be abandoned in favor of another hypothesis for which very general support has been found.

The new data on the dollar mark to be presented in this article fully support the conclusion reached in our previous articles,[7] from which we reproduce, by way of introduction, Fig. 1 taken from a copy of a letter written at New Orleans on September 12, 1778, by Oliver Pollock, "commercial agent of the United States at New Orleans," and sent to George Roger Clark, who was then heading an expedition for the capture of the Illinois country. The figure shows the close of this letter containing a financial summary, expressed in dollars. There are here five symbols written respectively to the left of the sums 1100, 5997, 328, 8550, 8613. Examining minutely the ones to the left of the first four sums, we find them to be p^s, made by a continuous motion of the pen, in this order: Down on the left, up on the right, the loop of the *p*, the *s* above. On the other hand, the symbol to the left of 8613 is made by two motions: One motion is down and up for *p*, the other motion is the curve for the *s*, one symbol being superposed upon the other. This last symbol is our modern dollar mark. According to the evidence supplied by the manuscript of Pollock's letter, our $ is a modified p^s, the Mexican abbreviation for "pesos" or "piastres," or "pieces of eight." The chief modification consists in bringing the *s*, in p^s, down upon the *p*. In Mexican manuscripts going as far back as the sixteenth century the abbreviation p^s can be found. The practice of raising the last

[7] A full summary of the previous articles is found in F. Cajori, "History of Mathematical Notations," Vol. 2, 1929, pp. 15–29.

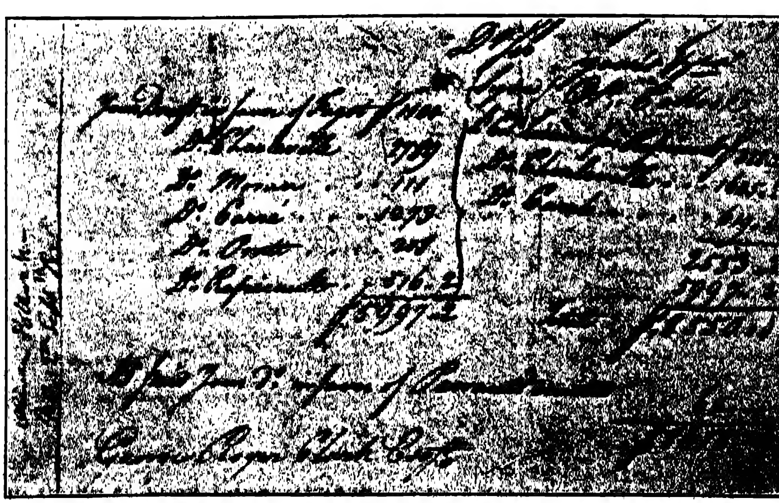


FIG. 1. THE ORIGIN OF THE DOLLAR MARK, AS SHOWN IN THE COPY OF A LETTER SENT BY OLIVER POLLOCK, FROM NEW ORLEANS, ON SEPTEMBER 12, 1778.

letter in abbreviations was almost universal among the Mexicans. Our dollar mark arose among those writers who were less addicted to the practice of raising terminal letters in abbreviations. If our views are correct, then the dollar mark might spring up in different places, quite independently, among various writers. And such was the case.

That the symbol in Pollock's letter was written in New Orleans is significant. The Gulf of Mexico and the Caribbean Sea constituted the American Mediterranean. Boats navigated the Mississippi River. On the Gulf coast and the West Indian islands people of different nationalities gathered, and commercial intercourse took place. These were the distributing centers for goods and also for coins. We quote from W. G. Sumner[8] certain phrases which show the connection between the American colonies and the West Indies. He tells of the trade Massachusetts had with the West Indies. He states that "scarcely had specie come into circulation in Massachusetts, when it was found that, although the remittance had been in silver, gold from the West Indies [then an inferior currency] began to stay in the colony"; trade of New York with "the West Indies" was about 1720 "wholly to the advantage of New York." "Coin was now coming freely [into New England] by trade with the West Indies." A similar statement is due to J. K. Upton:[9] "All the colonists were anxious to retain silver as a circulating medium and their trade with the West Indies brought considerable silver coin," but did not stay in the colonies because laws were enacted creating inferior legal tender. In the West Indies, the peso or Spanish dollar was in more general use than other coins, such as doubloons and joes. Westergaard[10] mentions also the rigsdaler, slettedaler, florin, ducat, livre and mark.

A proclamation[11] in Dutch, issued on February 22, 1760, at Fort Amsterdam in St. Martin, a West Indian island, forbids giving protection to Negroes from the island of St. Croix, on penalty of the sum mentioned in Fig. 2. The symbol

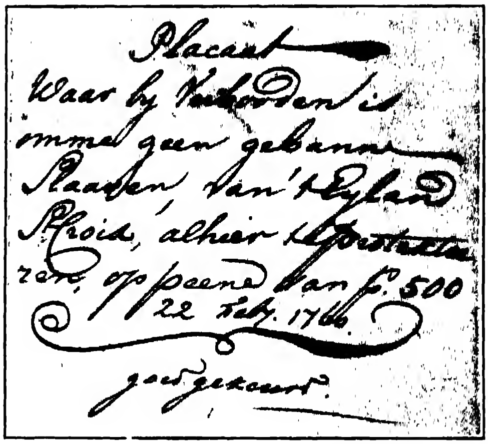


FIG. 2. FROM A PROCLAMATION ISSUED AT THE WEST INDIAN ISLAND, ST. MARTIN, ON FEBRUARY 22, 1760, AND INDICATING A PENALTY OF, APPARENTLY, $500, FOR GIVING PROTECTION TO SLAVES FROM THE ISLAND OF ST. CROIX.

placed before the 500 may mean "piastres" ("pesos") or perhaps "guilders." The shape of the symbol suggests a p[s], rather than the letter G which does not call for the long downward or upward stroke on the extreme left. Another Dutch document, of the year 1790, writes out in full "piastres Gourdes" and indicates that this Haitian coin circulated among the Dutch. It is our interpretation that the symbol in Fig. 2 stands for "piastres." If this is correct, then we see in the document of 1760 a part-way descent of the letter *s* upon the letter *p* and, therefore, a step toward the formation of our dollar mark.

Positive evidence of a West Indian modern dollar mark is found in a record of the sale of Negro slaves in Porto

8 William G. Sumner, "History of American Currency," 1876, pp. 8, 34, 40, 42.

9 "Money in Politics," Boston, 1884, p. 7.

10 W. Westergaard, "The Spanish West Indies under Company Rule (1671–1754)," New York, 1917, pp. 34, 92, 206, 225.

11 Bancroft Library, University of California, Danish West Indian Collection.

Rico.[12] The early entries use the Mexican sign p^s for pesos, but a little before July 1, 1778, a new handwriting appears, containing several times the p^s, but six times also the double symbol p^s \$, as in Fig. 3, which shows 1443 pesos and 2 reales. The doubling of the letters occurs for reales as well as for pesos. What does this sign signify? Simply the marking of the plural by repeating the letters, a practice which is prevalent to-day in the Spanish "E.E. U.U." to signify "Estados Unidos" and in the English "pp." for "pages" and "LL.D." for "Doctor of Laws." This doubling is of prime importance in our problem of the origin of the dollar mark, for it clinches the argument with compelling force, that the \$ descended from p^s. It is of interest to note that the earliest appearance of this symbol in the sale-record of slaves is April 1, 1778, a date only about five months earlier than the date of Pollock's letter. A later document, also written in the Spanish language, which contains the double symbol p^s \$, was written on August 29, 1800, at S^n. Marcos de Apalache, in Florida, and addressed to the noted Marquis de Casa Calvo in New Orleans,[13] who was then interim governor of the colony.

There is a diary kept in the State of New York by Ezra l'Hommedieu in which, between August 1, 1776, and December 5, 1776, the dollar sign occurs fourteen times, at first with only one downward stroke, but the last three times with two downward strokes.[14] Mexican manuscripts indicate that sometimes the letter *p* in p^s was written with one stroke only, instead of the more usual downward stroke, followed by an upward stroke. The letter *s* written over the p with a single stroke would naturally give rise to the form \$ of the dollar mark in place of the more usual \$. L'Hommedieu was a member of the New York Provincial Assembly and recorded in his diary some of the financial transactions of the assembly. As a member of the Continental Congress he wrote, in 1800, a letter[15] containing the symbolism "\$106 : 60."

In earlier articles[16] we have given facsimiles of dollar signs approaching the

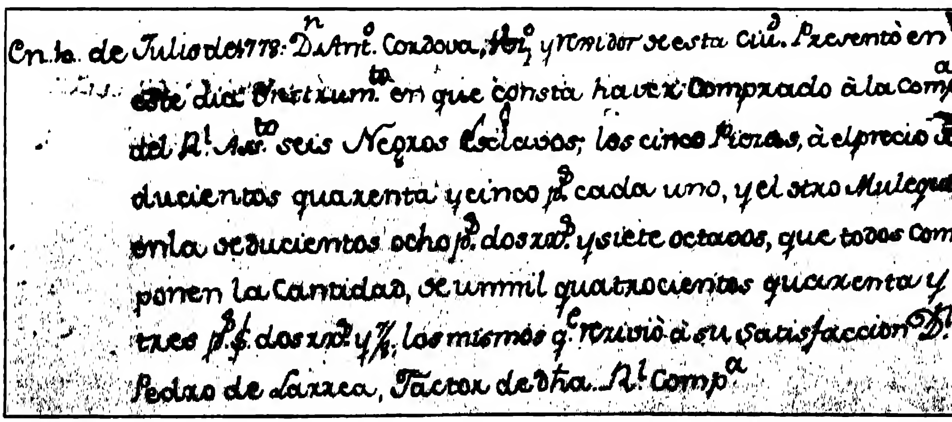

En 1o. de Julio de 1778: Dn. Antt. Cordova, Hon. y Regidor de esta Ciud. Presentó en este dia Instrumento en que consta haver comprado à la Compa. del Rl. Asto. seis Negros Esclavos; los cinco Piezas, à el precio de ducientos quarenta y cinco ps. cada uno, y el otro Mulegue en la de ducientos ocho ps. dos rs. y siete octavos, que todos componen la cantidad de un mil quatrocientos quarenta y tres ps. \$ dos rs. y 7/8, los mismos q. recivió à su satisfaccion Dn. Pedro de Larrea, Factor de dha. Rl. Compa.

FIG. 3. THE USE OF p^s AND \$ SYNONYMOUSLY TO REPRESENT "DOLLARS," IN A MANUSCRIPT RECORDING THE SALE OF SLAVES AT PORTO RICO. THE DATE OF THIS SALE IS JULY 1, 1778.

12 Bancroft Library, 1768–1779, Porto Rico. Real Companía del asiento de Negros.

13 Bancroft Library. Louisiana Papers. Letter of Petro Olivier.

14 For drawing of symbols, see F. Cajori, *op. cit.*, Vol. 2, p. 25.

15 Library of the Historical Society of Pennsylvania, Dreer Collection.

16 F. Cajori, *op. cit.*, Vol. 2, p. 22.

modern forms, occurring in letters written in New Orleans (1783 and 1786), on the Mississippi (1787), in Philadelphia (1792), in Nouvelle Madrid, Mo. (1793 and 1794), in New Orleans and Philadelphia (?) in 1796, at Louisville (?) in 1799. The modern sign occurs frequently in a ledger kept by George Washington, now preserved in the Omaha Public Library. The earliest date in the ledger is January 1, 1799. The sign appears also in a letter of September 29, 1802, now kept in the Harper Memorial Library of the University of Chicago. It is written by William A. Washington and relates to land above the Potomac belonging to the estate of George Washington.

What has been regarded as the earliest appearance of the dollar mark in print is in Chauncey Lee's "American Accomptant," published at Lansingburgh, New York, in 1797. But Lee's sign for "dimes" is more nearly our modern dollar mark than Lee's sign for "dollars."[17] The modern dollar mark occurs in the arithmetics of Daniel Adams (1807), an anonymous author (1811), Samuel Webber (1812), Jacob Willetts (1817).[18] We have seen the dollar mark in the *Boston Patriot* of September 1, 1810. Ernest Horn, of Iowa City, informs us that "The Epistolary Guide" of James Hardy, published at New York in 1817, gives the $ in all models of letters referring to amounts expressed in dollars. The Mexicans, at the time they achieved their independence from Spain (1821), were not yet using the $ in print. In a Mexican book of 1834 on statistics,[19] both the ps and $ are used. Our $ was introduced into Hawaii by American missionaries in a translation of Warren Colburn's "Mental Arithmetic"[20] in 1835.

The Spanish-Americans placed their p^s after the numerals, as in 65 p^s, while the English colonists, being accustomed to write £ before the number of pounds, usually wrote the $ to the left of the numerals, thus $65. It is placed after the numerals in some letters written by Joseph Montfort Street[21] in Prairie de Chien, Wisconsin, and in Rock Island, Illinois, in 1832 and 1836. It is placed sometimes before and at other times after the numerals, in letters and account books of the English trader William Petty Hartnell,[22] of California, and of John Begg at Lima, Peru, who was in trade relations with Hartnell in 1820 and later. In fact, in a letter of May 15, 1825, signed by McCullogh, Hartnell and Company, one finds "17727." In the newspaper *La Prensa* of 1910, in Buenos Aires, the $ frequently follows the numeral in the short advertisements, but precedes the numerals when arranged in columns.

Our conclusion is that the modern dollar mark is a modification of the Mexican sign p^s for pesos or piastres, the chief alteration being the lowering of the letter *s* upon the letter *p*. As the result of extensive and careful empirical study, this conclusion is now as firmly established as is the origin of any other monetary symbol, and more securely fixed than is the origin of any mathematical symbol which is not the conscious invention of some known individual. Nevertheless, from the examination of more manuscripts, much additional detail may be gathered on the spreading of the dollar mark in the United States and the American continent.

[17] For facsimile of Lee's symbols, see F. Cajori, *op. cit.*, Vol. 2, p. 27.

[18] For exact references, see F. Cajori, *op. cit.*, p. 28.

[19] J. A. Escudero, "Noticias estadísticas del estado Chihuahua," Mexico, 1834.

[20] Copy of translation in the Newberry Library, Chicago.

[21] Iowa State Historical Department. Letters of Joseph Montfort Street.

[22] Bancroft Library. Hartnell letters and account books.

JOHANNES EVANGELISTA PURKINJE
(1787-1869)

By Dr. VICTOR ROBINSON
EDITOR OF "MEDICAL LIFE," NEW YORK

To tarry at a discovery to its complete exhaustion, a discovery which casts a glamour about other names, was not Purkinje's habit. Driven from one discovery to another, he leaves the details to others; his works are stimulating data for further research. In addition, there are two rare qualities in this exalted spirit: respect for the youngest of talents, and modesty in not speaking of himself: both of these go with his noble character, but they are also to blame for Purkinje's achievements not being honored as they should be.

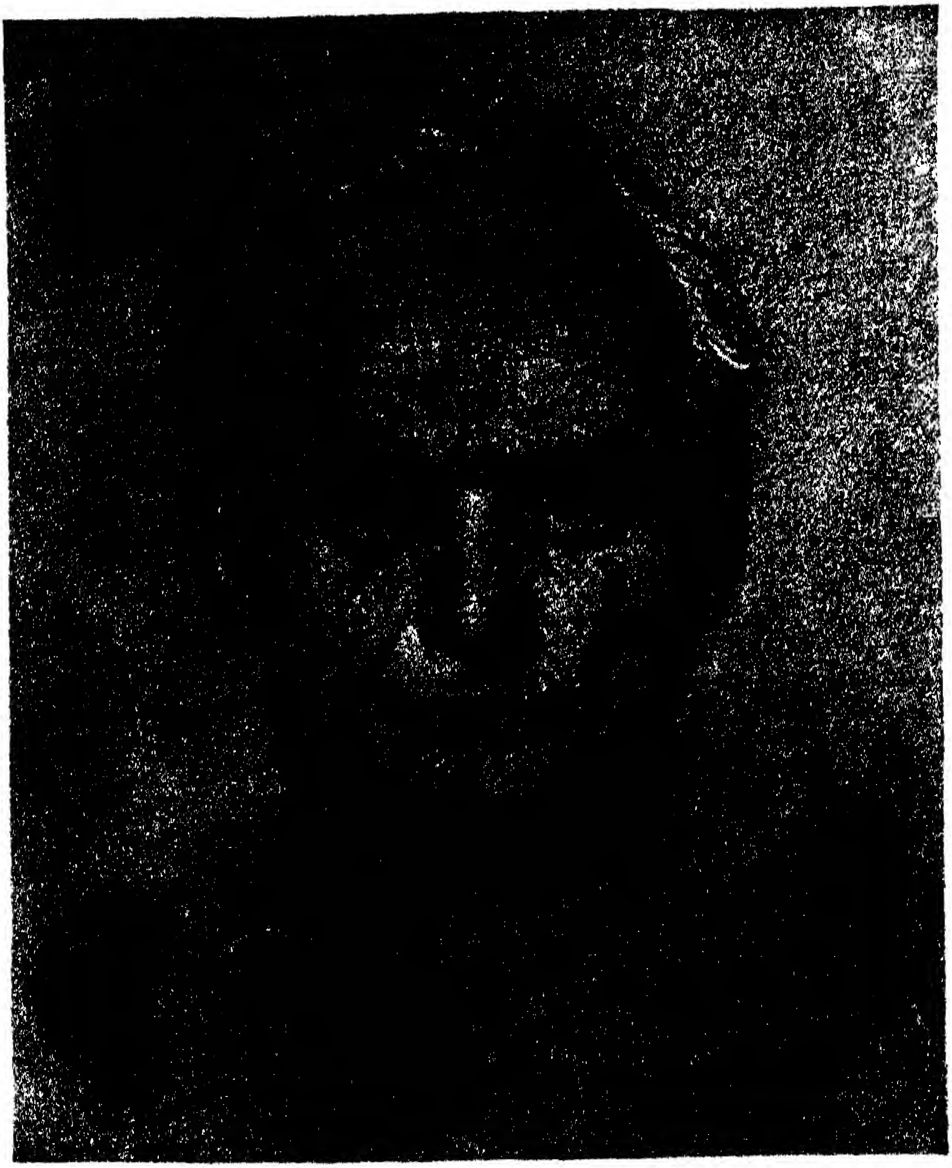
—*Th. Eiselt, 1859*

The village of Libochowitz is not on the average map, but it lies near Leitmeritz on the Elbe, a town situated amid such natural beauty that it is known as the Bohemian Paradise. Man has ever done his utmost to despoil all earthly paradise, and during that terrible period which history calls the Thirty Years' War—when a whole generation of humanity shed its blood over myths—most of the families that still remained above ground departed from this region.

The call of the soil is strong, and though the plow turn up bullet and skull, corn grows well on land that has been watered with blood. The healing years passed over Libochowitz, and the fields of Baron Herberstein were under the care of Agricultural Official Purkinje. His family must have occupied quarters in the baronial home, for here his wife, Rosalie Safranek, gave birth to her son Jan on December 17, 1787. Thus Johannes Evangelista Purkinje came into the world in the castle of Libochowitz, and not in a "peasant's hut," as is stated by R. Burton-Opitz and others. For purposes of biography, it is more interesting to be cradled in a peasant's cottage than in a nobleman's palace, but history is inexorable.

The young Purkinje attended school in his native village, and took lessons in music and singing, in accordance with the Czech fashion of those days. His voice paved the way for his further education, and he was sent as a chorister to the Piarists in Moravia, where he devoted himself to philology. He graduated from the normal school in Mikulov, and then completed the course in the gymnasium. When it became necessary to select a profession, Purkinje found that he had grown accustomed to the Piarists and was attracted to pedagogy, and for these reasons entered the Order of the Piarists as a teacher of ancient languages. His novitiate year was spent in Stará Voda near the Silesian border, whence he was transferred to Stražnic; after 1806 he proceeded to Litomyšl—all little towns which mean nothing to the reader unless he be Czech. The peace of monastic teaching must have appealed to him in many ways, yet he did not take the vow, and Fichte lured him from the monastery to the university. He had already learned French and Italian—later supplemented by various other modern tongues—and had read widely.

He bade farewell to the Piarists, and came to his country's capital to study philosophy. At Prague he occupied himself also with literature, and for a time thought of becoming a man of letters. He was as frugal as David Hume, and the meager fees he received by tutoring enabled him to live, for in those days scholars possessed the secret of subsisting on ideals. His chief pupils were the young barons, Schutterstein and Ferdinand Hildeprandt; Purkinje



PURKINJE
By Joseph Mánes

looked forward with keen pleasure to accompanying the latter to the Stavnic Mining Academy in Slovenia, but his dream was shattered when Hildeprandt joined the allies in the campaign against Napoleon.

Well-educated but still without a profession, Purkinje now decided upon medicine. It was never his intention to become a practicing physician, but he felt that the medical sciences would give him an insight into nature. Even toward the conclusion of his medical studies, the pedagogue's mantle clung to him, and he thought of asking the aid of the Hildeprandt family to establish a special teaching institution of the natural sciences, and he contemplated a visit to Switzerland to acquaint himself with the methods of Pestalozzi and his disciples. In 1818 he acted as assistant in anatomy and physiology under Rottenberg and Ilg, and in 1819 graduated with a dissertation on the subjective aspects of vision. He was already thirty-two years old, an age at which many famous scientific careers have closed.

The year 1819 was a troubled one for German students. August von Kotzebue, not content with his popularity as a playwright, had returned from Russia to his fatherland in the capacity of the czar's spy. Establishing a weekly newspaper, he ridiculed the students for their national aspirations, and especially mocked their efforts to secure free institutions. A clever man, the columns of his journal were funny and cruel, but a certain theological student had no sense of humor and killed him. The dagger of Karl Sand gave Metternich his opportunity to muzzle all Germany. Freedom of speech and press were abolished by the Carlsbad Decrees, students were condemned to death for wearing a ribbon, private papers in private houses were searched without warrant, journalists went into hiding, the naturalist Oken fled to Switzerland, professors and pupils emigrated to America and privy councillor Wilhelm von Humboldt, throwing down his portfolio in despair, relinquished politics forever to devote himself to the mysteries of the Basque tongue and the old Kawi language of Java. Wise Wilhelm von Humboldt! It is always a relief to turn from the world to the cloisters of culture.

In this year the bitter genius of Schopenhauer gave to the German people his masterpiece, but they were in no condition to read the "World as Will and Idea." They paid more attention to a pamphlet written by Hartwig Hundt, later suppressed by the censorship, in which the novelist made the suggestion, "As for the children of Israel, let them be sold to the English who could employ them on their Indian plantations instead of the blacks. In order that the tribe may not increase, let the men be emasculated, and their wives and daughters lodged in the houses of shame." In times of reaction, all sorts of ideas come to people's heads. Through the turmoil and general consternation, one man remained Jove-like, aloof, serene, going forward with his love affairs and work: Goethe, unperturbed by Napoleon, was unaware of Metternich. Among innumerable other activities, carrying on his researches in colors, Goethe read Purkinje's thesis with admiration, admitted that it stimulated him greatly, and quoted it frequently. The Bohemian physiologist, like the rest of the world, came to the oracle at Weimar, and Goethe was astonished at his personality and devotion to science. "Such an autodidactic and self-tormenting, talented Piarist," said Goethe, "represents a strange contrast in the midst of the Protestants." It was inevitable that among Goethe's crowded laurels should be entwined this leaf:

> I have taken the liberty of dedicating to you the second edition of my researches on "Sight from the Subjective View-point," since I could not resist making my strenuous mental efforts a memorial of my sentiments. Let us disregard

PURKINJE
Oil Painting by Peter Maixner

the fact that the work has been reprinted at the same time in a medical journal; this was not according to the original intention, and is a tribute which my poverty has been compelled to pay to booksellers as the manuscript wandered around hopelessly for a year. I hope this little volume will stir up a little more the phlegmatic interest of the Germans.

I wish to draw Your Excellency's attention to the appearance of the color-spectrums which could also be exploited in the field of applied art, inasmuch as according to the personal observations of Wach, the Berlin painter, the shady parts in colored drapery yield a clear dark color only when they obtain a light covering of contrasting hue, when the objective produced by the subjective which has been created by the illuminative parts are eliminated.

I am also sending you a specimen of my researches in the development of the bird's egg before laying.

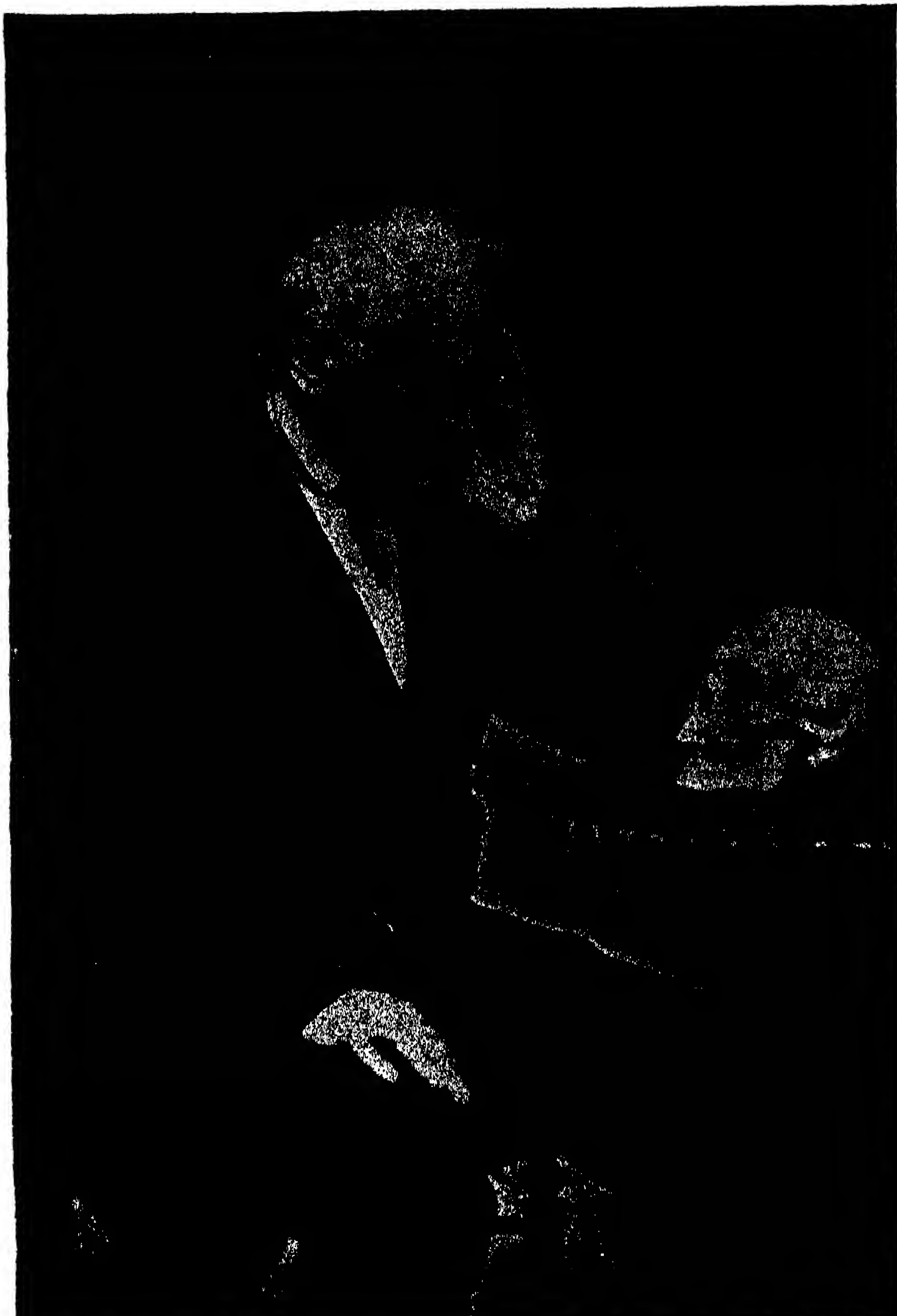
May you enjoy, with God's help, yet for a long time, your life so precious to us all.

J. Ev. Purkinje

While serving as house-tutor in Blatná in the family of Baron Hildeprandt, Purkinje had met the Baroness Adelaide Desfours. In those days literature was potent to move men and women, and after reading Schultze's poem, "Enchanted Rose," Adelaide confessed that "she felt in her heart the magic spell and her life blossomed out into full bloom." She found herself overwhelmed with love for the gifted tutor, but an aristocratic lady must be discreet, and love was translated into friendship. Twenty-two of her letters, written to Purkinje after his graduation, remain as evidence of this stifled passion: in the last of her correspondence, she tells him of her mother's death, reproaches him with not having answered her former letter, and while informing him that she has rejected a proposal, advises him to marry. Purkinje remained silent, but he did not forget, and in later years published Kacer's version of "Enchanted Rose."

Before this edition appeared, Ernst Daniel August Bartels, probably the first professor of physiology in Germany, was called from Breslau back to the older university of Marburg where he had previously taught. Purkinje was among the candidates for the vacant chair, and was rejected by the professors who did not look with favor upon the unknown Slav. They did not reckon, however, with two great European powers who stood behind Purkinje, and since the combination of Goethe and Alexander von Humboldt was irresistible, Purkinje in 1823 went to Breslau in spite of the faculty. He found himself an unwelcome guest of the university, and his chair was not lined with velvet. Naturally he spoke German with a tinge of Czech accent, and the anatomist Otto sarcastically informed him that if he wished to be understood, he would better lecture in Latin. Purkinje was not eloquent in expounding theories, and when he hinted that up to the present a lecturer in physiology was "merely a mechanism by means of which the theories of the old masters were repeated again and again," his classes dwindled in indignation and the faculty circulated a petition for his removal.

Later Purkinje stirred up more trouble by asking for a microscope. The authorities could not understand why a physiologist needed a microscope, and they sighed for the good old days of Bartels. There was the famous Bartels, becoming a Geheimrat and climbing to the Berlin chair; writing many books on *Naturphilosophie*, medicine and theology; diagnosing all diseases with the most learned phrases and knowing enough to denounce such new-fangled notions as Laennec's stethoscope; and yet he never needed a microscope. If this were permitted to go on, the university would be cluttered up with apparatus and specimens, and the students would be occupied in performing experiments instead of reading van Helmont and Haller and Bartels. Evidently the arguments failed to convince Purkinje, for in an unoccupied corner of the college building he



PURKINJE
A CONTEMPORARY PHOTOGRAPH

opened the first physiological laboratory. Had John Hunter tried to install his museum in St. George's Hospital, he would not have aroused more opposition than Purkinje with his laboratory, which seemed to his colleagues utterly useless in medicine. Moreover, Otto, officious and esthetic, objected strongly to the stench. Purkinje solved the difficulty by transferring the laboratory to his own house, and thereafter he lived and dined and slept in the midst of physiological equipment—including the unavoidable odors. His wife was not supposed to complain, since she was the daughter of the scientist Rudolphi.

In estimating the place of Purkinje in science, it should be remembered that he antedated the great experimental physiologists whose names are so familiar to-day. When Purkinje published his thesis in 1819, Johannes Müller was just entering the University of Bonn, Claude Bernard was a child of six, Brown-Séquard and Carl Ludwig were infants, Du Bois-Reymond was celebrating his first birthday, Brücke was uttering his first cry and Helmholtz and Huxley were yet unborn.

The test of a scientist's character is his relationship to obscurer workers. Marshall Hall, in announcing the existence of a system of excito-secretory nerves, did not mention Henry Fraser Campbell, for he had never heard of the American. Dr. Campbell, insisting that he had anticipated Marshall Hall and Claude Bernard in this discovery, forwarded to the English investigator a long letter and abstracts of his publications. The great Marshall Hall, then in his last illness, could easily have been too occupied to concern himself with the claims of the Georgia physiologist, and Campbell would have been forgotten. Instead, he sent a communication to the *Lancet*, giving the young doctor such full and generous credit that Campbell was encouraged to collect his essays into a volume which he dedicated to Marshall Hall "in high admiration of his genius, and in heartfelt acknowledgment of his liberality." This idyll of physiology is rare enough, while contests over priority are frequent, wordy, often vindictive and seldom settled. Instances in which teachers appropriate the labors of their pupils with inadequate recognition are not unknown even at the present day.

In this respect, Purkinje was particularly chivalrous and free-handed: he frequently incorporated his most important researches into dissertations which were signed by his students. Of course it was Carl Ludwig who developed this habit into a fine art. When Martin Barry, notable as the first to observe the union of the spermatozoon with the ovum, worked with Purkinje and showed him his essay on fiber, Purkinje translated it for him and had it published in Müller's *Archiv*. Another pupil was Gabriel Valentin, who increased our knowledge of taste and touch, of nucleus and nucleolus, and whose "Manual of the Development of the Fetus" was the first systematic treatise on embryology—a mighty worker was Valentin in his day, ranging various fields, but his name has been almost submerged under the never-ceasing output of his successors. It was not the fate of Purkinje to leave behind him a school like Johannes Müller or Carl Ludwig, but we may say of him as Helmholtz said of Müller: "Whoever comes into contact with men of the first rank has an altered scale of value in life. Such intellectual contact is the most interesting event that life can offer."

Purkinje could have made his discoveries in a hayloft, yet academic life must have had its attractions, for he retained his chair for over a quarter of a century. His work was the most important produced in the Silesian university until the advent of Ferdinand Cohn, who after building the foundations of bacteriology at Breslau, helped Robert Koch lay the corner-stone there by his demonstration of the life-history of an-

thrax: Cohn wrote the great news to Darwin, and the old biologist replied, "I well remember saying to myself, between twenty and thirty years ago, that if ever the origin of any infectious disease could be proved, it would be the greatest triumph to science; and now I rejoice to have seen the triumph."

Gradually the personal character and exceptional attainments of Purkinje gained recognition at Breslau. Students came to his classes and laboratory, his colleagues acknowledged his services, his small salary was increased to more respectable proportions, much-desired apparatus was secured and in time the Prussian government erected for him a separate building devoted exclusively to physiology—this first Physiological Institute was opened on November 8, 1839, and forty years passed before Berlin followed Breslau. Purkinje had reached his goal, but the fire of his genius had exhausted itself, and most of his great discoveries, the mere list of which still amazes us, had already been made in his own home. He admitted that "many promising investigations await the time when I shall have regained my lost love of work," but the fallow years proved that the ardor of youth had gone. He was indeed pleased at the tribute to his labors and science, although he no longer had the strength or enthusiasm to nauseate and sicken himself with huge doses of digitalis in order to study disturbances of vision. Moreover, administrative duties and requisitions for supplies are incompatible with research. It is pleasant to be a director or a dean, but who ever heard of a dean discovering anything? Purkinje now neglected his hard-earned compound microscope to translate the lyrics of Schiller into Czech.

The following letter written by Purkinje during his latter years at Breslau exhibits his interest in his seventeenth century countryman, the great schoolmaster whose theological performances were unfortunate, but whose name will always survive in the history of education as one of the first rationalists in pedagogy. We are indebted for this letter to the courtesy of Purkinje's grandson, Dr. Cyril Purkyně, director of the Státní Gelogický Ústav Československé Republiky:

Breslau, August 29th, 1844.

My dear friend:

That I am with you in spirit, although far away for the past two years, you may judge from my effort to join you and share with your vicissitudes until death. With the assistance of Mr. P. H. Klebelsberk I have obtained Austrian citizenship for which I applied last year, and this year I have presented through this same gentleman my request for the chair of physiology at the University Praha, to Count Kolowrat. I doubt whether it would be advisable to inform Mr. Nádherný regarding this step, as he seems to shun my free thinking, although he himself has recently suggested to me to apply for transfer. My petition for citizenship has been presented upon his advice, and perhaps without need. His second suggestion was to send a petition to the Emperor, although my citizenship definitely includes my right (for which I have asked) to apply for appointments to the institutes of learning in Austria. I presented myself to Türkheim and later upon the advice of K. to Kolowrat. We shall see what the result will be. From the enclosed letter of the Rev. Sidewice, Lésno, Prussia, you will note that I have reopened negotiations for the purchase of the manuscript of Comenius and that they now seem to be more approachable, perhaps because of the fact that the Gymnasium Director, Mr. Scholor, who was the one who chiefly insisted to retain and exhibit the manuscript together with the relic and portrait of Comenius in the gymnasium library, has now been transferred to Erfurt. I do not see from your letter that Čelakovský could have given you any information about it, as you certainly would not have been silent on the subject and thus frustrated my many years' effort.

I would have replied to your letter earlier, but I did not want to come to you emptyhanded and so I copied for you from Comenius' own manuscript, rewritten and reedited church songs, introduction, which might be published in the Musejnik as an example of writing of that time.

Should the Museum Committee definitely not wish these manuscripts, please have them send

me a few lines in German for my verification. You will kindly return to me Sidewice's letter.

I look forward to an early response from you and with my respectful greetings to your wife and kisses to your children, I am,

Your devoted
JAN PURKYNĚ

As previously stated, Purkinje's first work was in physiological optics. Thrice he wrote his name in this field: Purkinje's figures, Purkinje's images and Purkinje's phenomenon. A bibliography of the contributions to these subjects during a century would show how a large number of investigators received their impulse from Purkinje. The work of Purkinje was germinative, for even if it consisted of only a few paragraphs, it proved reproductive. His method of lighting the retina, his measurements of the curvatures of the lens and cornea, his studies of the refracting surfaces of the eye with mirrors not only anticipated the ophthalmoscope of Helmholtz, but even made it inevitable.

The name of Francis Galton is usually associated with the foundation of finger-print identification, but seventy years earlier, Purkinje wrote: "The wonderful arrangement and design which are on the palm of the hand and upon the sole of the foot, and especially the little hollows on the fingertips, the papillary lines, command our attention." He then proceeded to describe with accuracy the unchanging character of finger-prints, illustrated with various figurations. His pioneer work is of value to all criminologists, and the English penitentiary inspector, Major Arthur Griffiths, author of the "Chronicles of Newgate," writes: "The permanent character of the finger-print was first put forward scientifically in 1823 by J. E, Purkinje, an eminent professor of physiology, who read a paper before the University of Breslau, adducing nine standard types of impressions and advocating a system of classification which attracted no great attention." With G. Rosche, we may call Purkinje the old master of dactyloscopy.

Most pre-Virchovian workers, including Purkinje, are rather roughly handled in the "Cellular Pathology," but Virchow credits Purkinje with having devised the term *corpora amylacea;* he also introduced the terms *enchyma, cambium, protoplasm* and others—almost reminding us of Walther Flemming who in a single year increased the nomenclature of cytology with *mitosis, amitosis, karyomitosis, dyaster, karenchyma, net-knot, spireme, mitome, karyoplasm* and *interfilar substance.* Richard Mead, relying on the experiments of Galen, felt safe in swallowing the poison of vipers, but Purkinje broke new ground in some of his self-experiments with belladonna, camphor, digitalis, opium, stramonium and turpentine.

Every investigator of the first rank has conducted a host of minor researches, and among Purkinje's innumerable ones may be mentioned: an early paper "On the World of Dreams," now over a century old, which should be read to-day in the light of Freudism; the contribution to acoustics, "On Tartini's Tones"; his auscultation experiment, by which he was able to determine the points of rest and motion of a vibrating plate, without employing Chladni's sand; his work on rhizopods, the nautilus, and embryology of the tadpole; his original description of the peculiar formation of the skin of cucumber plants, and his observations of the methods of fertilization in the plant world.

More important investigations, and belonging chiefly, but not exclusively, to his first sixteen years at Breslau, were his contribution to photometry; his observation that deaf-mutes can hear through the bones of the skull; his experiments upon the production of vertigo which paved the way for the knowledge of nystagmus; his work with Pappenheim on artificial digestion which antedates Schwann, including the demonstra-

tion of the dissolving power of acidulated infusion of pancreatic juice; his researches with Valentin on ciliary epithelial movement and the explanation of its independence of the nervous system; his original description of bone, cartilage, blood-vessels, gastric glands and special organs; his discovery of the sudoriferous glands and their ducts; of the flask-shaped Purkinjean nerve-cells with their axones and branching dendrites which form the characteristic features of the cerebellum, and of the Purkinje fibers in the cardiac muscle. In microscopy he was the first to use the microtome, microphotography, Drummond lime light, glacial acetic acid, potassium bichromate and Canada balsam.

There is much confusion in regard to discoveries of the nucleus: standard general and medical dictionaries give incorrect information, and Locy, although he devotes much space to it, in no way clarifies the subject. We have frequently read the statement that Purkinje in 1825 discovered the nucleus of the human ovum; this is manifestly impossible when we remember that the mammalian ovum itself was not discovered until two years later by von Baer. What Purkinje did discover was the nucleus or germinal vesicle in birds, announcing his find in the *Gratulationschrift* to Blumenbach; he was likewise the first to use the term *protoplasm* for the embryonic formative substance. Misstatements concerning Purkinje are prevalent: for example, Littré, in his classic Dictionnaire de Medecine, actually refers to him as *anatomiste hongrosis;* while Dorland, after thirteen editions of his popular dictionary, repeats this error, and gives the date of his death as 1850! A man whose connection with the cell doctrine was as intimate as Purkinje's deserves more accuracy on the part of lexicographers. If Schleiden and Schwann are the fathers of the cell-theory, Purkinje is at least its great uncle, for prior to Schleiden and Schwann he taught that organs consist of cells and nuclei, and suggested the probable identity in the structure of animal and plant cells. In this, however, he was not without various forerunners.

Since the universal cell is now recognized as the basis of life, we should be familiar with a chronology of cytology, and many of the earlier dates and facts will be found in that storehouse of biological knowledge, Johannes Müller's book. It is a pity that this great manual of physiology should have been superseded by later productions, for in numerous respects it has never been equaled. Even to-day, with a little editing and some foot-notes, it would serve admirably, for as far as we recall, the only passage that is entirely obsolete is the following: "Woman is distinguished by her modesty, meekness, patience and amiability; by her readiness to sacrifice her own good and herself for the sake of others; by her tenderness, sympathizing disposition, and piety. The field of her activity is her home and family."

If it be asked why Purkinje spent twenty-six years in a foreign country, the answer is simple: for the same reason that Kaspar Wolff, the founder of modern embryology, journeyed from his native Berlin to spend his last thirty years in Russia. Purkinje had applied for a chair in Prague, but they were filled with long-lived occupants, or the authorities appointed what Huxley would call a "safe nobody." Wolff may have grown accustomed to Catherine the Great, but in spite of his success at Breslau, Purkinje felt an expatriate, and cast many longing glances toward his own soil—more than once he sought an opportunity for returning, but Bohemia was not yet ready for her greatest son. Purkinje was a true Czech, and Tyl's "Kde domov můj" stirred him as if he were a gymnasium

student. Fortunately for his reputation, he was not guilty of the extravagances of the great Swedish anatomist, Olof Rudbeck, who, ignoring his real discoveries, regarded the "Atlantican" as his chief work—huge folios claiming that after Noah's flood, the land which Japheth sought and found was Sweden, the Almighty's favorite spot on earth. How men of intelligence can do these things is really beyond comprehension.

Purkinje finally returned to Prague as professor of physiology. "Well do we remember," says a Czech writer, "how Purkyně's coming in 1850 was celebrated not only in Prague, but in all the provinces." Old and famous, he was no longer compelled to fight for a laboratory: the Austrian government gave him a splendid one, with a capable assistant and an adequate salary. Purkinje was over sixty, and he proved that apparatus alone can not make discoveries.

It would be entirely erroneous, however, to believe that he had retired, or that his intellectual activity was at an end. The days of his epochal discoveries were indeed over, but he had made enough for an entire institute of research. He now busied himself with Czech politics, and whoever did that in the mid-nineteenth century was much occupied—he was elected to the senate and served with exemplary diligence. The pen is often the staff of age, and Purkinje wrote copiously; he was a founder and editor of the journal of natural history, *Ziva,* and for several years one of its principal contributors. He vitalized the *Journal* of the Bohemian Museum, and his popular essays in the Bohemian language stimulated interest in nature. He continued to develop the ideas of Pestalozzi, and discussed the establishment of orphan asylums from a scientific standpoint. Josef Klika was able to produce a lengthy monograph devoted exclusively to "Purkinje as a Pedagogue."

There are few scientific workers of the scope of Purkinje of whom as little is generally known. His name does not once occur in Baas, although that thick and valuable volume is at times overloaded with forgotten names. If an explanation is sought of this and similar omissions elsewhere, it is found partially in the fact that Purkinje, by returning to Prague and not identifying himself with the Vienna school, stood apart from the main stream of German medicine—indirect but potent testimony of the influence of the Vienna school. Distinguished medical travelers, such as Richard Bright and those who followed in his footsteps, have left their impressions of medical Vienna, but Prague was out of the way.

It would not be correct, however, to cite Purkinje as an example of genius overlooked by his contemporaries and neglected by posterity. Even when he ceased to keep up with the progress of physiology, and younger giants overstepped his own frontiers, he was not disregarded. In fact, to read nice things about himself he was not obliged to follow the usual custom and wait for the obituary notices. In 1859, the distinguished Eiselet published an accurate analysis of Purkinje's work, occupying twenty printed pages; in 1867, an appreciative biographical sketch appeared in *Světozor,* concluding with the passage:

> . . . the greatest reward and one which is dearest to him is the unbounded affection with which our entire nation clings to him, the proof of which was apparent last summer when he passed through some parts of the land. Wherever he appeared citizens endeavored to honor him; the day of his coming was a day of celebration. He is truly not only honor-deserving, but a really lovable personage. Whoever sees him must love him. He has lived eighty years, and certainly not in leisure, but he still walks with vigor and enjoys splendid health; it seems as though nature herself wishes to mark her ardent admirer and worker.
>
> His faculties are excellent, and he who would count upon his "aged memory," would be much surprised. His humor retains its original fresh-

ness; he likes to be in company and contributes to conversation his characteristic wit. He has never known idleness and despises it now: he must be active, always, either in his own branch, or he finds other work and pursues it with youthful enthusiasm. Only recently he translated the "Evangelium" of Sallet, and Barthriari's "Book of Love"; he edited the original Austria Polyglotta, and learned the difficult Magyar tongue: he practices his violin, etc.

We can not do better in taking leave of this noble and beloved son of our nation than to call heartily *Mnogaja leta!* [many years].

In 1868, the Bohemian Medical Society at Prague published a quarto—*Quod bonum, felix, faustum fortunatumque sit, Joanni Ev. Purkyně, diem semisaecularem X. dec. 1868 summorum in medicina honorum in alma antiquissimaque universitate Pragena celebranti gratulatur.* . . . The obituary notice in the *Proceedings* of the Royal Society of London, after summing up his unusual achievements, states:

In 1848 he attended the meeting of the Slavonic races in Prague, and was present at the celebration of the five hundredth anniversary of the foundation of the university, when the degree of doctor of philosophy was conferred upon him. A long-cherished wish to be enabled to pass the remainder of his days in his native country was gratified. . . . His election as a foreign member of the Royal Society took place in 1850. He was corresponding member of the French Institute, member of the academies of Vienna, Berlin and St. Petersburg and of many other learned societies. He retained his vigor of body and mind up to the last days of his life. His death, after an illness of no long duration, on the 28th day of July, 1869, was mourned by every class of society in Bohemia.

When we think of that trinity of astronomers, Horrocks, Gascoigne, Crabtree: Jeremiah Horrocks, discovering the transit of Venus across the sun, and in terror that his Sabbath duties as a parish curate would prevent him from observing this phenomenon, practically a beggar, without leisure for science, in broken health, dead at the beginning of his twenties, and from his grave teaching a Newton; his friend, William Gascoigne, inventor of the micrometer, slain in his youth at Marston Moor, leaving his work unfinished; his other friend, William Crabtree, corrector of the Rudolphine Tables, likewise disappearing early from the banquet of life in an unknown manner—we are thankful that Purkinje, like Goethe and Humboldt, was spared by fate to write *Finis* to his labors. At the time of his death, Purkinje was in his eighty-second year. Happy is the pioneer who becomes a patriarch, and at whose bier a grateful and sorrowing nation bows its head.

Now that Purkinje's beloved Bohemia has emerged as an independent country, the Republic of Czechoslovakia is adding new laurels to the name of Purkinje. Kamil Lhoták v. Lhota, professor of pharmacology at Prague, edited a handsome volume of Purkinje's original monographs. Paul J. Hanzlik, of Stanford University, informs us of the sad fact that Dr. Lhoták died young of gastric carcinoma, but no doubt other devoted hands will carry on the work. Professor Hanzlik has also directed our attention to two volumes recently issued by the Czech Medical Society of the personal correspondence of Purkinje, containing letters sent to him from a considerable number of people in all walks of life and from all over Europe—the nobility, statesmen, publicists, poets and scientists.

Foreign countries have also not forgotten him. E. Thomsen, of the University of Copenhagen, published in the *Skandinavisches Archiv für Physiologie* a study of Purkinje for which he received a gold medal. In a personal letter to Henry Jerry John, of the Cleveland Clinic, Dr. Thomsen writes: "There does not exist any reprint of my article on Purkinje. That work was written when I was a poor student, unable to buy reprints!"—here, then, is an important function for the photostat. Dr. John is the chief Purkinje student in

this country, and after several years of effort has collected, in many volumes, practically everything that has been written by and about his illustrious countryman. We can not permit this occasion to pass without acknowledging our indebtedness to Dr. John for placing at our disposal his patiently accumulated data and the illustrations which adorn his essay; when we add that Dr. John himself is planning a biography of Purkinje, yet readily granted prior use of his material, his generosity will be realized. A definitive biography of Purkinje, sixty years after his death, is much desired, for his influence lives: the *Quarterly Cumulative Index Medicus* for 1928 seems to contain more references to Purkinje and his work than to any other physiologist of his era. It is the glory of Purkinje that he holds a foremost place among the investigators who found physiology a speculative subject and left it an experimental science.

Hradčany Hill with its castles and cathedrals has seen a thousand years of battle, and for centuries the waters of Vltava have been reddened by intolerance. Towers upon towers, and those black Towers of the Abandoned. This is the story of Prague, and it is also the story of every capital in Europe. Climbing the Petřín, looking over Prague to the Giant Mountains, and from the heights of Moravia's frontier to the Bohemian Forest, how magnificent would be the view if we did not know that every inch of soil was bloodstained. Prague is beautiful—Humboldt calls it the most beautiful inland town of Europe—and to enter this historic threshold would be a feast for the soul, could we but forget the aggressions of kings and the endless strife of conflicting sects in the name of the Prince of Peace. . . . That wonderful old clock with the moving apostles and the crowing cock is still ticking the time—the clock that told the hours before Columbus set sail for America and immortality. Those countless moss-grown tombs in the ancient and crowded burial-ground of the Jews—under the elder-trees, the teacher tenderly surrounded by his thirty-three scholars. To Prague in his broken years came that master of the moon, Tycho Brahe, and here are his remains and relics; after him followed a pock-marked vagabond from a public-house to capture a planet for a mad emperor—John Kepler's "Commentaries on Mars" helped fulfil the prophecy of Libussa: "I see a city whose glory touches the stars." Monuments of monarchs and warriors—several recently removed from the public squares and hidden in museums. Let these medieval spirits disappear forever, until there glows across humanity's sky the sunrise that shall never set, burning away the barriers that divide the human race, revealing at last to the children of Mother Earth that none can be aliens and all are brothers. . . . Wandering through the streets of Prague, in the aimless yet interested fashion of tourists, we came suddenly upon a simple house with a plain tablet stating that this was the house of Purkinje. To the student of science this is the most inspiring spot in all Prague, for here lived the man who standing humbly before truth, read many of nature's secrets, and thus enlarged the human horizon.

SPACE, TIME AND EINSTEIN[1]

By Dr. PAUL R. HEYL

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WHETHER we understand it or not, we have all heard of the Einstein theory, and failure to understand it does not seem incompatible with the holding of opinions on the subject, sometimes of a militant and antagonistic character.

Twenty-four years have elapsed since Einstein published his first paper on relativity, dealing principally with certain relations between mechanics and optics. Since that time a new generation has grown up to whom pre-Einstein science is a matter of history, not of experience. Eleven years after his first paper Einstein published a second, in which he broadened and extended the theory laid down in the first so as to include gravitation. And now again, thirteen years later, in a third paper, Einstein has broadened his theory still farther so as to include the phenomena of electricity and magnetism.

In view of the rekindling of interest in Einstein because of the appearance of his latest paper it may be worth while to reexamine and restate the primary foundations upon which his theory rests.

The general interest taken in this subject is frequently a matter of wonder to those of us who must give it attention professionally, for there are in modern physical science other doctrines which run closely second to that of Einstein in strangeness and novelty, yet none of these seems to have taken any particular hold on popular imagination.

Perhaps the reason for this is that these theories deal with ideas which are remote from ordinary life, while Einstein lays iconoclastic hands on two concepts about which every intelligent person believes that he really knows something—space and time.

Space and time have been regarded "always, everywhere and by all," as independent concepts, sharply distinguishable from one another, with no correlation between them. Space is fixed, though we may move about in it at will, forward or backward, up or down; and wherever we go our experience is that the properties of space are everywhere the same, and are unaltered whether we are moving or stationary. Time, on the other hand, is essentially a moving proposition, and we must perforce move with it. Except in memory, we can not go back in time; we must go forward, and at the rate at which time chooses to travel. We are on a moving platform, the mechanism of which is beyond our control.

There is a difference also in our measures of space and time. Space may be measured in feet, square feet or cubic feet, as the case may be, but time is essentially one-dimensional. Square hours or cubic seconds are meaningless terms. Moreover, no connection has ever been recognized between space and time measures. How many feet make one hour? A meaningless question, you say, yet something that sounds very much like it has (since Minkowski) received the serious attention of many otherwise reputable scientific men. And now comes Einstein, rudely disturbing these old-established concepts and asking us to recast our ideas of space and time in a way that seems to us fantastic and bizarre.

What has Einstein done to these fundamental concepts?

He has introduced a correlation or connecting link between what have always

[1] Publication approved by the director of the Bureau of Standards of the U. S. Department of Commerce.

been supposed to be separate and distinct ideas. In the first place, he asserts that as we move about, the geometrical properties of space, as evidenced by figures drawn in it, will alter by an amount depending on the speed of the observer's motion, thus (through the concept of velocity) linking space with time. He also asserts in the second place that the flow of time, always regarded as invariable, will likewise alter with the motion of the observer, again linking time with space.

For example, suppose that we, with our instruments for measuring space and time, are located on a platform which we believe to be stationary. We can not be altogether certain of this, for there is no other visible object in the universe save another similar platform carrying an observer likewise equipped; but when we observe relative motion between our platform and the other it pleases our intuition to suppose our platform at rest and to ascribe all the motion to the other.

Einstein asserts that if this relative velocity were great enough we might notice some strange happenings on the other platform. True, a rather high velocity would be necessary, something comparable with the speed of light, say 100,000 miles a second; and it is tacitly assumed that we would be able to get a glimpse of the moving system as it flashed by. Granting this, what would we see?

Einstein asserts that if there were a circle painted on the moving platform it would appear to us as an ellipse with its short diameter in the direction of its motion. The amount of this shortening would depend upon the speed with which the system is moving, being quite imperceptible at ordinary speeds. In the limit, as the speed approached that of light, the circle would flatten completely into a straight line—its diameter perpendicular to the direction of motion.

Of this shortening, says Einstein, the moving observer will be unconscious, for not only is the circle flattened in the direction of motion, but the platform itself and all it carries (including the observer) share in this shortening. Even the observer's measuring rod is not exempt. Laid along that diameter of the circle which is perpendicular to the line of motion it would indicate, say, ten centimeters; placed along the shortened diameter, the rod, being itself now shortened in the same ratio, would apparently indicate the same length as before, and the moving observer would have no suspicion of what we might be seeing. In fact, he might with equal right suppose himself stationary and lay all the motion to the account of our platform. And if we had a circle painted on our floor it would appear flattened to him, though not to us.

Again, the clock on the other observer's platform would exhibit to us, though not to him, an equally eccentric behavior. Suppose that other platform stopped opposite us long enough for a comparison of clocks, and then, backing off to get a start, flashed by us at a high speed. As it passed we would see that the other clock was apparently slow as compared with ours, but of this the moving observer would be unconscious.

But could he not observe our clock?

Certainly, just as easily as we could see his.

And would he not see that our clock was now faster than his? "No," says Einstein. "On the contrary, he would take it to be slower."

Here is a paradox indeed! *A*'s clock appears slow to *B* while at the same time *B*'s clock appears slow to *A*! Which is right?

To this question Einstein answers indifferently:

"Either. It all depends on the point of view."

In asserting that the rate of a moving clock is altered by its motion Einstein has not in mind anything so materialistic as the motion interfering with the proper functioning of the pendulum or balance wheel. It is something deeper and more abstruse than that. He means that the flow of time itself is changed by the motion of the system, and that the clock is but fulfilling its natural function in keeping pace with the altered rate of time.

A rather imperfect illustration may help at this point. If I were traveling by train from the Atlantic to the Pacific Coast it would be necessary for me to set my watch back an hour occasionally. A less practical but mathematically more elegant plan would be to alter the rate of my watch before starting so that it would indicate the correct local time during the whole journey. Of course, on a slow train less alteration would be required. The point is this: that a timepiece keeping local time on the train will of necessity run at a rate depending on the speed of the train.

Einstein applies a somewhat similar concept to all moving systems, and asserts that the local time on such systems runs the more slowly the more rapidly the system moves.

It is no wonder that assertions so revolutionary should encounter general incredulity. Skepticism is nature's armor against foolishness. But there are two reactions possible to assertions such as these. One may say: "The man is crazy" or one may ask: "What is the evidence?"

The latter, of course, is the correct scientific attitude. To such a question Einstein might answer laconically: "Desperate diseases require desperate remedies."

"But," we reply, "we are not conscious of any disease so desperate as to require such drastic treatment."

"If you are not," says Einstein, "you should be. Does your memory run back thirty years? Or have you not read, at least, of the serious contradiction in which theoretical physics found itself involved at the opening of the present century?"

Einstein's reference is to the difficulty which arose as a consequence of the negative results of the famous Michelson-Morley experiment and other experiments of a similar nature. The situation that then arose is perhaps best explained by an analogy.

If we were in a boat, stationary in still water, with trains of water-waves passing us, it would be possible to determine the speed of the waves by timing their passage over, say, the length of the boat. If the boat were then set in motion in the same direction in which the waves were traveling, the apparent speed of the waves with respect to the boat would be decreased, reaching zero when the boat attained the speed of the waves; and if the boat were set in motion in the opposite direction the apparent speed of the waves would be increased.

If the boat were moving with uniform speed in a circular path, the apparent speed of the waves would fluctuate periodically, and from the magnitude of this fluctuation it would be possible to determine the speed of the boat.

Now the earth is moving around the sun in a nearly circular orbit with a speed of about eighteen miles per second, and at all points in this orbit light waves from the stars are constantly streaming by. The analogy of the boat and the water-waves suggested to several physicists, toward the close of the nineteenth century, the possibility of verifying the earth's motion by experiments on the speed of light.

True, the speed of the earth in its orbit is only one ten-thousandth of the speed of light, but methods were available of more than sufficient precision to pick up an effect of this order of magnitude. It was, therefore, with the greatest surprise, not to say consternation,

that the results of all such experiments were found to be negative; that analogy, for some unexplained reason, appeared to have broken down somewhere between mechanics and optics; that while the speed of water-waves varied as it should with the speed of the observer, the velocity of light seemed completely unaffected by such motion.

Nor could any fault be found with method or technique. At least three independent lines of experiment, two optical and one electrical, led to the same negative conclusion.

This breakdown of analogy between mechanics and optics introduced a sharp line of division into physical science. Now since the days of Newton the general trend of scientific thought has been in the direction of removing or effacing such sharp lines indicating differences in kind and replacing them by differences in degree. In other words, scientific thought is monistic, seeking one ultimate explanation for all phenomena.

Kepler, by his study of the planets, had discovered the three well-known laws which their motion obeys. To him these laws were purely empirical, separate and distinct results of observation. It remained for Newton to show that these three laws were mathematical consequences of a single broader law—that of gravitation. In this, Newton was a monistic philosopher.

The whole of the scientific development of the nineteenth century was monistic. Faraday and Oersted showed that electricity and magnetism were closely allied. Joule, Mayer and others pointed out the equivalence of heat and work. Maxwell correlated light with electricity and magnetism. By the close of the century physical phenomena of all kinds were regarded as forming one vast, interrelated web, governed by some broad and far-reaching law as yet unknown, but whose discovery was confidently expected, perhaps in the near future. Gravitation alone obstinately resisted all attempts to coordinate it with other phenomena.

The consequent reintroduction of a sharp line between mechanics and optics was therefore most disturbing. It was to remove this difficulty that Einstein found it necessary to alter our fundamental ideas regarding space and time. It is obvious that a varying velocity can be made to appear constant if our space and time units vary also in a proper manner, but in introducing such changes we must be careful not to cover up the changes in velocity readily observable in water-waves or sound waves.

The determination of such changes in length and time units is a purely mathematical problem. The solution found by Einstein is what is known as the Lorentz transformation, so named because it was first found (in a simpler form) by Lorentz. Einstein arrived at a more general formula and, in addition, was not aware of Lorentz's work at the time of writing his own paper.

The evidence submitted so far for Einstein's theory is purely retrospective; the theory explains known facts and removes difficulties. But it must be remembered that this is just what the theory was built to do. It is a different matter when we apply it to facts unknown at the time the theory was constructed, and the supreme test is the ability of a theory to predict such new phenomena.

This crucial test has been successfully met by the theory of relativity. In 1916 Einstein broadened his theory to include gravitation, which since the days of Newton had successfully resisted all attempts to bring it into line with other phenomena. From this extended theory Einstein predicted two previously unsuspected phenomena, a bending of light rays passing close by the sun and a shift of the Fraunhofer lines in the solar spectrum. Both these predictions have

now been experimentally verified. This aspect of the subject has been elsewhere discussed by the present writer.[2]

Mathematically, Einstein's solution of our theoretical difficulties is perfect. Even the paradox of the two clocks, each appearing slower than the other, becomes a logical consequence of the Lorentz transformation. Einstein's explanation is sufficient, and up to the present time no one has been able to show that it is not necessary.

Einstein himself is under no delusion on this point. He is reported to have said: "No amount of experimentation can ever prove me right; a single experiment may at any time prove me wrong."

Early in the present year Einstein again broadened his theory to include the phenomena of electricity and magnetism. This does not mean that he has given an electromagnetic explanation of gravitation; many attempts of this kind have been made, and all have failed in the same respect—to recognize that there is no screen for gravitation. What Einstein has done is something deeper and broader than that. He has succeeded in finding a formula which may assume two special forms according as a constant which it contains is or is not zero. In the latter case the formula gives us Maxwell's equations for an electromagnetic field; in the former, Einstein's equations for a gravitative field.

But in spite of the formal success of Einstein's attempt to bring order into theoretical physics, his theory lacks the cordial support of many persons, including a certain number of conscientious scientific men. To conservative minds his theory has no natural attractiveness. By some such it is accepted on a purely tentative basis, for lack of a better explanation, while others refuse to accept it at all, as fantastic, bizarre and opposed to common sense.

But the history of science teaches us the danger of relying too much on common sense. When Mayer, in the nineteenth century, came to the conclusion that work could be converted into heat, his doctrine seemed as fantastic to the Victorian physicists as Einstein's theory appears to any one to-day. The ***Annalen der Physik*** refused to publish Mayer's paper. One of his critics said to him: "Why, man, this is against common sense! If what you say were true, water could be warmed by merely shaking it!"

Mayer felt the force of this argument, and for some time could find no reply. Finally, weeks later, it is said, he walked into his friend's presence and without preface announced: "It is!"

Common sense is a great turncoat. To-day, if any one were to assert that water could be shaken without being warmed, he would have the common-sense argument used against him. "Common sense" is too often a synonym for inherited and traditional modes of thought. As Eddington says, the cosmos is undoubtedly regulated by sense, but not always by common sense.

With the honest doubter of relativity the writer has unlimited sympathy, for he himself was for some years of that company. Such a one is in no comfortable frame of mind. He knows that scientific questions are not decided by majorities; he remembers the long reign of the phlogiston theory and the later N-ray delusion, but he can not witness without misgivings the steady movement of his respected fellow scientists to enlist under the Einstein banner.

There is a disease to whose insidious attack every one of us is liable. Let us call it psychosclerosis. When one has thought in a certain way for a long time it is often difficult to see the force of the evidence for anything revolutionary.

[2] "The Common Sense of the Theory of Relativity," SCIENTIFIC MONTHLY, December, 1923; "The Present Status of the Theory of Relativity," SCIENTIFIC MONTHLY, July, 1926.

The great Agassiz never accepted the doctrine of evolution, though every one of his students did. Kelvin to the end of his days found it difficult to believe that the energy emitted by radioactive bodies came from within the atom. He clutched at straws, searching for some unsuspected type of radiation in space, absorbable only by those bodies which we call radioactive.

Psychosclerosis, it seems, may develop at any age. Some exhibit it before reaching years of discretion; others, a few fortunate ones like Lorentz, may remain plastic to the end of the chapter. It will be well worth while for any honest doubter of Einstein to give this point serious consideration. The writer himself was for some years unable to see the force of the evidence, but largely in consequence of the failure of an experimental venture of his own which was designed to prove Einstein wrong, he (like his namesake nineteen centuries ago) saw a great light, and has since been a supporter of the doctrine of relativity.

Einstein's aim from the first has been to bring order, not confusion; to exhibit all the laws of nature as special cases of one all-embracing law. In his monism he is unimpeachably orthodox.

But there are other monistic philosophers besides scientific men. You will recall Tennyson's vision of

> One law, one element,
> And one far-off, divine event
> To which the whole creation moves.

SCIENCE AS A SOURCE OF IDEAS

By Dr. M. LUCKIESH

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A DISCUSSION of this subject necessarily must be founded upon an understanding of two terms—science and idea. An idea may be defined as a definite mental conception believed to be true or possible, and I shall accept that definition provided *belief* is based upon systematized foundational knowledge. Unsupported belief is nothing more than a guess. Guessing has no limitations and it can be applied by any one to everything.

Aristotle believed that if two balls, equal in size but differing in mass or weight, were dropped from the same height at the same time, the heavier would fall more rapidly than the lighter one. This conception was not founded upon knowledge. It was not a sound idea; it could never be a valuable idea; it was not a good idea, and doubtless it was not a new idea. It was a guess, nothing more, even though it appeared reasonable. Many persons unacquainted with science and uninhabited with the modern spirit of experimentation would even now make the same guess. Aristotle had an idea wholly devoid of knowledge. Our definition of an idea is not broad enough to include such an idea as Aristotle's, for I shall consider *valuable* ideas as the only kind having their source in science. Scientists, temporarily out of their rôle or off their scientific base, can have poor ideas, too, but science should not be blamed for scientists. However, scientists associated with organized knowledge and basing their reductions upon established facts have to listen to more poor ideas without the foundation of knowledge than they can possibly create in all their off moments.

If Jules Verne in one of his fascinating tales had included a telescope by means of which one of his supermen could see the past history of the earth, in my opinion this would not have been an idea. I would not credit him with even a part of a valuable idea because many could and perhaps have made the same guess or have indulged in this same fancy without any consideration or knowledge of how the telescope could be made to yield the results. But if I should devise a super-telescope in my mind, in which optical magnification was pressed to its practical limit, then light was converted into electricity, then the electricity was enormously amplified, then electricity was converted into light, this would be a reasonably sound idea, because in the main it is theoretically possible. Then if, in my mind's eye, this super-telescope were directed upon the minutest mirrors—facets of crystals—on far-off celestial bodies, owing to the finiteness of the velocity of light I could see the past events upon the earth. By choosing mirrors at various distances, measured in light-years, I could see any past event which the weather conditions then and now permitted. The whole is an idea constituting a device and its applications. If this apparently theoretically possible idea could be realized in a practical device it would be valuable.

If it should have occurred to me when I was a boy that it would be desirably convenient to charge a storage battery by heating it in the kitchen stove, this would not be a sound idea as far as I was concerned. In fact, at best it would be a wild guess because at that time I knew nothing of the laws of thermody-

namics. However, if I had had sense enough to take this thought to a scientist and he found that it did not transgress thermodynamical laws I would have been entitled to some measure of credit. However, it was not the original thought, but the action, which entitled me to share in the eventually soundly constructed idea.

About three hundred years ago the greatest idea of all the ages took definite form. It was the idea of science—knowledge produced by experimentation. It was the result of an awakening to a new conception of nature—that nature was ruled by law rather than by a capricious or whimsical god and, therefore, that nature could be understood and was worth understanding.

Galileo was one of the first standard-bearers of the new idea. He tested a long-standing belief by dropping two balls, of the same size but of unequal weight, from the same height, and found that Aristotle and all who believed with him for two thousand years were wrong.

The great idea which took definite form at that time was born in a belief-ridden civilization. A new group—scientists—was born into that world. Then began a great struggle which is still going on—between beliefs and knowledge. I do not refer to the so-called spiritual world, but to the material one. A scientist in his proper rôle can have a two-compartment mind. In one he is entitled to beliefs pertaining to the spiritual world, if they brighten his outlook upon life, even though they are not supported by a shred of knowledge. In the other compartment there is no need for beliefs. It contains facts—tested and testable ones—coordinated into laws—systematized. There is no doorway between these two compartments and, therefore, there can be no actual intermingling. Furthermore, there can be no true conflict between the two because they have nothing in common.

Of course, in the present discussion we are interested only in the material world of obtainable scientific knowledge. Science has no need for the word *belief* and the scientist either knows or he does not. Belief ranges from the slightest suspicion to complete assurance. Knowledge either is or it isn't. Of course, there are many gaps in knowledge and the scientist often must make his best guess in spanning them. Perhaps he may be said to believe this or that. But after all it is not belief; it is merely his best guess.

Knowledge alone is not science. It is a mass or mess of facts. The knowledge which comes by individual experience is so often faulty and fragmentary that only the knowledge tested by the experience of many, and then only by methods which minimize the effects of emotions and prejudices, is dependable. Science is the organization of these tested facts into relationships—into law and order. When the facts are insufficient, some guessing must be done as to the final relationships. Hypotheses are created. As the gaps decrease by the addition of new knowledge, theories evolve. Finally, when no gaps remain, the relationship is a law. Laws are then grouped into generalizations. What seemed to be a complex disorder has evolved into simplicity, revealing much of the workings of nature. Since the man of science is saturated with tested facts and with laws and principles, the probability of his guess being correct is greater than that of the guesses of others.

Individual facts can be put together into various patterns. These more or less complete patterns are ideas. It is in this way that the scientist or others may create valuable ideas. Inasmuch as it is inconceivable that any new idea can be so simple as to arise from a single fact, it may be concluded that all eventually valuable ideas are constructed from systematized knowledge. Therefore, science is the source of the material of all valu-

able new ideas. Sometimes the scientist creates the idea but often he does not, and he has several good alibis when he does not originate the idea. Even with the necessary facts before him often he fails to see the combination which leads to a new application of knowledge. He has no alibi for this excepting that he is merely human.

If we take all historical time beginning seven thousand years ago as being equal to the lifetime of a human being, the three hundred years since Galileo correspond to a three-year-old child. On this scale organized scientific research is an infant only three months old. The birth of the three-year-old changed the entire philosophical outlook of free-thinking men. It began an intellectual revolution and it established the necessary foundation for the material revolution which was to come later. More than two centuries elapsed before this pure-science outlook gave birth to organized research with an applied-science view-point. For the first time in all history lines of communication began to be partially established between industry and systematized fundamental knowledge. Even with these few and uncertain connections this three-months'-old infant has already revolutionized industry and man's manner of living. And this, notwithstanding a general lack of recognition or understanding of the functions of science and of scientists on the part of the commercial, industrial and engineering elements which necessarily are links in the lines of communication between science and public needs and demands.

Industry is as old as civilization. It is of the belief-ridden age and it has inherited much which still blinds it to the fundamentality and certainty of science. It evolved from a realm of uncertainty —of opinions, beliefs and partial truths —and it still uses these in creating, examining and in weighing ideas. It still does not completely comprehend that a foundation of tested systematized knowledge is available. When such knowledge is not incomplete or wholly unavailable, at least there is available in the scientist a more or less perfected art of research attack. Commercial and technical men, having grown out of the age in which the cart was before the horse, naturally tread blandly and blindly into the scientists' field instead of recognizing that they are only links between science and the public. Scientists, having sprung up recently, with no traditions and with no preordained place in business and industry, naturally tread uncertainly and often unwelcomed where others have long been established. As a consequence, the lines of communication necessary for the creation of valuable ideas are not as good as they should be.

When organized scientific research with an applied-science view-point got well under way, much was heard of pure science and applied science. For two hundred years following Galileo, scientific studies were pursued predominantly for the joy of discovery or, in that age of aristocracy, for the intellectual superiority which was the badge of such work. There developed an aristocracy of knowledge. Some scientific men even expressed the hope that their works would never be degraded by being useful. Twenty years ago there were still many of these aristocrats of knowledge accepting a living from a civilization which they, secretly at least, disdained to aid. Science and scientists have paid dearly for this attitude. But research from an applied view-point, vibrant with purpose and energetically alert, has made a name for itself, brought prosperity to those who paid the bill and much comfort and happiness to mankind. Applied or industrial scientists also made many fundamental discoveries and other additions to funda-

mental knowledge. To-day the pure scientist is rare who looks down upon the applied scientist. The aristocrats of knowledge are threadbare and antiquated. Applied research has become intellectually the peer of pure research. It is also much more difficult because it must surmount the obstacles in the path toward the objective. And the most serious obstacles are often the prejudices and other weaknesses of human beings in the path. Pure research is not as purposeful nor as definitely committed to an objective. It is more likely to detour or digress when the going becomes too difficult or seemingly impossible. As a consequence the relatively greater hardships have made industrial scientists as a rule more virile than the pure scientists. They are also more alert to the opportunities of science because at least they are on the edge of the maelstrom of the world's affairs, whereas pure scientists are relatively isolated.

Science necessarily supplies the material of which all valuable ideas are constructed. However, to pursue this subject further we must dissect an idea until we find what we may call the germ. One may dream or even investigate without purpose. These germs float in and out of the mind. If purposeful thinking takes hold of such a germ and the mind is stocked with systematized tested knowledge, a valuable idea may result and a poor idea will be recognized. For one mind to catch the germ and build it into a valuable idea has become increasingly difficult. In the early years of applied science there was great opportunity for the individualist. That was the heyday of the Edisons. Only as a new branch of science is opened are such opportunities available. They will come from time to time, but with less and less opportunity for the individualist. This century has witnessed the evolution from simplicity to complexity in all phases of science and industry.

Likewise civilization has grown complex. There was a time when every individual was relatively independent. He supplied all his needs. But times have changed. In addition to obtaining, possessing and using systematized tested knowledge, the scientist can not be expected to be the major creator of valuable ideas, the inventor, the manufacturer and the seller of the article any more than any individual can be expected to supply all his own needs in the present age. Still, under certain conditions of organization and human obstacles he must do all this. The industrial scientist at times should play all these parts or parts of each, but it is becoming increasingly difficult.

Science has grown very complex and extensive in its three hundred years of life, largely because of the universal availability of knowledge through printing and other kinds of communication. The scientist must keep his mind's eye upon this kaleidoscope of scientific works and publications. Besides his own studies he must file away for present and future use as much of this knowledge as possible. While doing this the world moves onward, public needs alter and the applications of products ramify. To obtain the greatest number of valuable ideas for his company he should have at least four lives to live in parallel. One would be spent out in the public's world learning what the public thinks, needs, desires and is getting from other sources. One life would be spent among the salesmen and engineers. One life would be lived inside the industry. One life would be given to his own studies. The germs of valuable ideas are to be found in all these places. He can do his best to spend some of his time in all these rôles and should create as many ideas as others equally concentrated upon their respective fields. But the most productive organization would be the connecting of these individuals or branches in such a manner that com-

bined they form a complete line of communication. But until the other links obtain a full conception of what science is and where it is to be found, germs of ideas which they catch may die before they can be built up with systematized knowledge.

Even in a progressive industrial organization it is not difficult, for one possessing the scientific view-point, to see the opportunities of science being wasted daily. Either the germ of an idea is not brought to science or science is not where the germ is. Of course, science is constantly producing, but I am trying to show how it could do more. For years I have seen technical researches and other activities being pursued by men who did not have a grasp of the fundamental laws and data underlying the work. Furthermore, there is an art of research which is best developed in those who have a clear conception of science and are guided by its spirit. Possibly science could be made to yield more valuable ideas if these technical men would develop the library habit. To one in the scientific field in which the reading or skimming of scientific journals has necessarily become a habit, the prevalent lack of acquaintance with the scientific work of the world on the part of most technical men engaged in researches and allied activities is shocking.

However, for an industry to get the most out of science, scientists should be intimately associated with technical departments and activities. Consolidation of these various view-points and talents establishes the best lines of communication and provides the greatest exposure to germs. Then, regardless of who catches the germ, it may be built into a valuable idea by the combined knowledge of the various individuals, and the waste due to poor ideas should be decreased. It is difficult to conceive of consolidation going so far as to include science with commercial activities, but the scientist, if he had the daily experiences of the commercial men, would catch many germs and some of them would become valuable ideas.

One of the difficulties is the temporal displacement of view-points. Primarily the salesman is interested in to-day; the commercial engineer in next month; the technical investigator in next year, and the industrial scientist in the more distant future. But they have in common the success of the business. To insure continued success, progress in products must be made. Each of the elements can play some part, however small, in catching germs and in passing them back along the line. Perhaps it may seem that I have gone somewhat afield in this discussion. I have purposely covered most of the territory where germs of ideas may be found in order to emphasize the importance of action and to show who can be active in aiding science to aid in industry.

Knowledge is valuable, but action is necessary. In the early years of applied science in industry, scientific knowledge was relatively meager but also most of its simplest applications had not been made. The industrial scientist had not arrived, but technical workers were already at work. By action they made up for the scarcity of scientific knowledge, in some degree at least. In that simpler period of simpler ideas and developments, action was generally more fruitful than thought. It was fruitless to think without scientific data, for this is the thought-stuff. That was the period of learning how; the era of knowing why was yet to come. Those were the years when, as Edison said, one was wise to try a fool experiment.

Since that time scientific knowledge has increased enormously in quantity and in complexity. In the development of ideas, thought has relatively increased in importance. Its fruitfulness increases

correspondingly with scientific knowledge which provides the stuff for thinking. Action, including keen observation with an alert mind, will always be necessary, and all the individuals in the line of communication between science and its applications must supply a part of the action if the utmost is to be obtained from science.

It is unnecessary to review the services which science has already rendered to modern industry. It has played an important part in the development of valuable ideas—sometimes including the germ stage, ofttimes afterward. With organizations designed to expose science to germs and germs to science, it should do increasingly more. It has many advantages. It is able to separate the ideas which are mere guesses from those which are sound. It always produces the valuable species of ideas. Some may not be economically valuable to a company but it is not necessarily the function of science to determine or to predict this. Any sound idea, however valueless from an economic view-point at the present time, will be valuable sometime, for it is inconceivable that in this complex world, which is growing more complex, any group of facts arranged into a sound idea could not be useful sometime somehow. Science eliminates haphazardness not only in the choice but also in the development of an idea. Science works directly with open eyes. A great amount of industrial research and development work is being prosecuted more or less blindly at the present time. The worker is blind in proportion to his lack of fundamental knowledge underlying his work and between him and his objective. The scientist is a sharpshooter with a modern rifle. The worker without scientific knowledge is using an antiquated blunderbus.

To accomplish the task which I have assumed, I shall utilize a recent idea created by Einstein. He found a way of confining a boundless universe in a limited space. He did this by inventing curved space, which gave a curvature to the universe. If an earth-being got astride a ray of light emitted and traveled in a straight line, as light is supposed to travel, eventually he would find himself at the place from which he began his journey. Any discussion involving science is boundless because science is. Still it must be limited. In order to be certain to confine a boundless subject in a limited space, I decided in the beginning to stop where I began. Before Einstein's invention, this could have been accomplished only by arguing in a circle, but I have Einstein to prove that I can do this by traveling in a straight line.

As I return toward the starting-point I find knowledge and science incompletely defined. I shall now complete the definition and correspondingly develop the picture of science. Since scientists came upon the stage of civilization, a new kind of knowledge has appeared. Before their time fundamental knowledge, at best, was qualitative. Little is really known concerning anything until it is measured quantitatively. We see a moving object. That alone is the type of knowledge of the prescience era. Measurements of direction, speed, size, shape, mass and constitution are the foundation and the framework of scientific knowledge. This kind of accurate detailed knowledge leads to a larger sphere of understanding by answering such questions as, When and why did the body start? What keeps it moving? Where is its destination? From these answers arise other questions and the sphere of relationships grows and grows.

The scientist develops measuring instruments more and more sensitive, and mathematics more and more adequate. These are the tools which have given us detailed knowledge. Without highly

accurate measuring methods Einstein would never have known the errors of Newtonianism. Without the most recent developments in mathematics he would not have been able to express himself. Without these we would still be in the pre-Einstein era of knowledge.

And so it goes on and on—the scientist is continually sharpening his tools, inventing new ones and extending their use. His production is detailed intimate expressive knowledge, and we profit greatly by some peculiarities of this product. Knowledge is invaluable; still, it can be given away without parting with it. Perhaps this is the major reason for its wide distribution. Knowledge is useless until it is used and it still exists after it is used. Certainly this is a good reason for using it. With these characteristics and the inestimable results of scientific knowledge in a relatively few years, should we wonder that civilization which got along without it for many centuries has adopted it for its foundation and is growing more and more dependent upon it?

In the earlier years of Edison, scientific knowledge was so meager that many simple ideas and developments awaited the technical worker. Edison himself discovered the phenomenon of electronic discharge between the terminals of a filament lamp. But he only learned that an electric current passed through the space between. The electron had not been discovered because measuring methods had not been developed to detect it. The entire radio art has been constructed since 1910 upon the accurate quantitative measurements of the preceding twenty years. Qualitative knowledge is only a step nearer certainty than opinions and beliefs. Accurate quantitative data are the essence of truth and certainty.

This is the kind of knowledge we can depend upon, and prejudices, emotions, opinions should not be permitted to hamper it. This is the kind of knowledge which is teaching us that more than man can imagine nature can achieve. This is the kind of knowledge that men, mere motes on an almost infinitesimal earth, are obtaining from atoms inconceivably small and from stellar laboratories inconceivably distant. Measuring instruments are limited, but the human mind is boundless, just as the universe is limited although it is boundless. Man's equipment is well adapted to explore all nature and to learn its secrets.

And the benefit of scientific knowledge should not and will not end with its utilization in material things. Only genius can extend the borders of scientific knowledge, but the humblest man can be taught its spirit. He can learn to distinguish between opinion and knowledge. He can learn to desire, to know and to face truth. Doubtless, human beings will always have their frailties, but as the scientific spirit infiltrates more and more throughout business and industry, and thence throughout civilization, it should develop honesty and tolerance and make better human beings. What can compete with the shrine of truth?

THE FOSTER CHILD

By PAUL POPENOE
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Most of the children available for adoption fall into three groups: (1) illegitimate children; (2) those abandoned by their parents; and (3) those who have been taken away from their parents because the latter were found unfit by the courts to retain the custody of their own offspring.

It is scarcely necessary to point out that in none of these cases is the ancestry likely to be up to par. The best are sorted out early by the child-placing agencies, in response to the demand for children to adopt, which everywhere in the United States exceeds the supply, girls being most desired. The remainder, collected in orphanages, represent predominantly the inferior levels and usually show up badly in tests. Congenital syphilis is abundant; superior intellect rare. Numerous examinations of the populations of such asylums have revealed that from one eighth to one half of the inmates may be classed as "normal." Most of the rest are either mentally deficient or at least backward; there are usually a few above the average, the proportion of these running in some instances as high as one eighth.

A group of 513 dependent children in Delaware, studied by the Children's Bureau, probably represents conditions in many other states. More than three fourths of these came from families in which there were unfavorable conditions, alcoholism and "immorality" being the commonest findings. Only 3 per cent. of the children were full orphans; most of them had both parents living but "no account." Three fourths of the children over seven had themselves records of delinquency.

Special studies made upon illegitimate children harmonize with these findings. An investigation in Boston showed that "at least 19 per cent. had a heritage in which there was known or probable insanity, feeblemindedness, or other subnormal or abnormal mental condition," while mental examinations of a series of unselected unmarried mothers from the obstetrical service of the Cincinnati General Hospital disclosed that "not more than 20 per cent. can safely be pronounced normal. From 40 per cent. to 50 per cent. of the unmarried mothers are almost without question of so low grade mentally as to make life under institutional care the only happy one for themselves, and the most economical and only safe arrangement for society."

Yet in another investigation the illegitimate children were found to be brighter and of better parentage than the legitimate children that were placed out. Among the latter, 89 per cent. of the fathers and 83 per cent. of the mothers were described as "either mentally or morally defective," as against 31 per cent. and 53 per cent. for illegitimates. Of course such figures are not exact, but they confirm the everyday knowledge that children from good homes are not customarily out looking for foster parents.

Reputable child-placing agencies, however, make every endeavor to place children under conditions that will be favorable. So far as possible, those with congenital syphilis are not sent out, unless to some one who understands the situation fully. If the child is old enough to be tested, its mentality is determined and the prospective foster parent advised. Ancestry, tradition, religion are taken into account. Among younger children the agency has little

chance to predict intelligence, and its clients seem to attach little weight to this. Most people stipulate that the child they are to take shall be healthy; apart from this they are more concerned about inconsequential and sentimental items than about the fundamentals, their attitude in this respect recalling that of many younger persons in selecting a husband or wife. Often a demand is made for a child on the spur of the moment. There is an authentic story of a woman who suddenly decided to adopt a baby shown her, because she thought it "would look so sweet" in a coat she could make from some pieces of left-over white fur. The sweet little thing thus adopted now has an IQ of 72.

A distinguished physician who is one of the most active men in the United States in promoting adoptions describes the situation gleefully. "People come up looking for girls," he says. "Of course they must all be golden-haired, blue-eyed, with dimples, impeccable ancestry and sweet dispositions. But all we do is to take the prospective parents up to the nursery, and some child holds out its arms to them, and it may be a black-haired boy picked up in an open lot somewhere, but they say, 'That's the baby I want.'"

A child who is placed in a foster home after the age of four or five knows, of course, that it is not his real home. Those placed earlier may not know unless told. In a New York investigation, half of the children placed under five were kept in ignorance of the foster relationship, while in a California investigation which dealt only with those adopted as infants, two thirds were ignorant. In this case, it was found that the most intelligent parents were the ones most likely to tell the child the truth.

Although hundreds of children are being placed out each year by scores of agencies, some of these show little concern over the future of their charges. They prefer to content themselves with pious hopes and fervent affirmations, and cite a few striking instances to justify the claim which most of them make, explicitly or implicitly, that any child will turn out well if given a proper home.

Such an exceptional child was probably the offspring of the black sheep of some able family. While his own parents may have been of little value, or even a detriment, to the community, they were yet able to transmit to their offspring good qualities which did not appear in their own lives. Thus one would expect, in a large group of dependent or illegitimate children, to find a few who carried some really good traits. There are a few other cases where a child of superior parents is set adrift for some unusual reason. Moses is the classical example, but Sargon I, king of Babylonia (2637–2582 B. C.), has almost identical childhood history and is an equally striking case in point.[1]

These isolated cases are easily matched by equally isolated and striking cases to the opposite effect, such as two boys (reported by L. M. Terman) adopted at the ages of five and seven from a very poor home. Their IQ's were 72 and 73. Four years later, after exceptional advantages, their IQ's were 70 and 77.

So far as I am aware, only one agency which places children has made any determined effort to find out how its children turn out. This is the State Charities Aid Association of New York,

[1] The number of legendary worthies whose supposed parents were not their real parents has aroused the ready suspicion of the psychoanalysts, and they have described "The Birth of the Hero" as one of the universal myths, based on an equally universal tendency of children to fancy, in their day-dreams, that they are not the offspring of their putative parents, but are really of nobler lineage. Questionnaires reveal that a large proportion of the population does, in fact, recall having such childhood fantasies. The number of histories comparable to those of Sargon and Moses can be multiplied readily by any one with a knowledge of ancient literature.

which published in 1924 a report on the history of 910 of its children. Briefly, it found that six out of every eight have "made good" in the sense that they have at least been able to manage their own affairs with ordinary prudence and live in accordance with the standards of their own communities. The seventh has turned out to be incapable but "harmless"; the eighth, definitely bad.

Although three fourths of the children are thus alleged to have become reasonably good citizens, this fact is not quite so encouraging as it appears at first sight to the family which contemplates taking in or adopting a child (only 269 of the children in this group were legally adopted), for the fact is that some of them had to go through two, three or more homes before they found one in which they could live satisfactorily. There were 1,621 homes used for the 910 children. In only 60 per cent. of the homes did the child turn out satisfactorily. It thus appears that the family contemplating taking in a foundling has a little better than an even chance not to regret the act.

Moreover, it must be remembered that this particular agency, which is one of the largest in operation, probably sifts its children with unusual care, to eliminate defectives. A smaller agency run with less efficiency and more sentimentality would be likely to place many children who were even less favorably endowed.

Furthermore, the children included in this study were in some cases still young—nearly half were minors. It is obvious that their "success" at the age of eighteen is not final, since they are mostly still under the control of their elders. The child who appears at eighteen or twenty to be behaving well may at twenty-eight or thirty tell a different story. At the lower age he is either still dependent or is just releasing himself from his dependent status. What will happen ten or twenty years later, when he is married, has more children than he can support, loses his youthful ideals, ambition and self-confidence, and begins to think that "the world has it in for him" and that it is no use to try to be a good citizen, since the ones who get ahead in life are merely the crooks who are clever enough to avoid detection?

It appears, then, that this study can not be taken at its face value; that the facts are probably not so favorable as appear from it.

Looking at the details more closely, one learns that the child placed in a bad foster home is just about as likely to turn out well as is the one placed in a good foster home. Even the worst parental home, it seems, is better than the best orphan asylum, if the child's future success in the world is the standard of measurement. These are striking and almost unprecedented findings, which need a good deal of substantiation before they will be accepted without question. The studies quoted later in this paper show that foster children put in good homes frequently made definite, sometimes relatively large, gains in IQ. The home brought out the best that they had in them. On the other hand, two groups of girls taken from bad surroundings and put in unusually good institutions failed to show any such advance. In another case, involving only six girls who were put in a very superior institution on the cottage plan, the average gain was but five points, and one showed a marked loss. Among one hundred children in two German orphanages, there was no relation between the level of intelligence and the length of time that the children had spent in the institution. Brothers and sisters are not made any more alike intellectually by being kept in an orphanage for years.

In all these instances, the institution was doubtless much more impartial, much more efficient, much more hy-

gienic, much more "scientific" than the home. But it failed in comparison with the home because the latter apparently provided something necessary for child development which the former could not furnish. A consideration of this fact is recommended, in passing, to those who think that the old-fashioned family is an obsolete institution, and who look forward to a time when the state will assume the care of all children as soon as they are weaned, thereby setting parents free for "careers."

What, then, in the light of the New York report, makes the difference between the child's success and failure in a foster home? Two factors are named: (1) early placement, and (2) a sympathetic relationship with the foster parents. To some extent (2) is merely a phase of (1). This report, then, puts almost the entire weight of the child's success on being adopted young.

Important as this fact is, few will believe that it is strong enough to support the entire weight of the superstructure. When one looks more carefully at the figures, one finds that of full brothers and sisters, put into equally suitable homes so far as one can judge, 40 per cent. turned out quite differently from each other. Here is the factor of heredity, of which the report had previously lost sight. The parental traits segregate out in the children; some get more than their share of the good ones (and it is scarcely necessary to remark that even the worst family has a few good traits); some get more than their share of the bad.

The conclusions of the study just mentioned are borne out, in part, by two particularly careful studies, one in Illinois (Frank N. Freeman, *et al.*) and the other in California (Barbara S. Burks). These were concerned primarily to find how far the child's general intelligence could be brought up by good surroundings.

The Illinois study is the most nearly comparable with that of the New York agency, for it dealt with children placed out at all ages. The conclusion it reached was that early placement and a good foster home were the most significant features in permitting a child to do his best. Although the background of the children was bad, it was found that in good homes there were few serious cases of misbehavior.

The California study is particularly interesting in dealing only with children placed as babies—all of them under one year of age and most of them at about three months. It therefore had an ideal opportunity to measure the total effect of environment acting after birth. It appears from this study that all of the factors of home environment taken together account for something like 17 per cent. of the differences in intelligence among children. The total contribution of heredity seemed to be about 75 per cent. or 80 per cent. The small remainder must be assigned to the sort of chance and accidental influences that are always present in development.

Of the influence assigned to heredity (75 per cent. to 80 per cent.), a third was allotted to the parents. The rest belongs to the more remote ancestry. Usually, the influence of the parents is thought of, and properly so, as including also that of all their progenitors; but if one is making a separate study of the various influences that account for the differences in IQ among children, it is legitimate to attempt to apportion the responsibility in more detail, as in this instance.

This study also gave an almost unique opportunity to determine how much an IQ could be changed by the greatest possible improvement or impairment of the environment, acting from birth onward. The conclusion was reached that in such extreme conditions, it might be altered as much as twenty points, but

that such extreme conditions would not be reached in more than a home or two in a thousand. Rough as the present methods of measuring mental traits are, then, they do succeed to a useful degree in getting at the real innate intelligence of a child; and 70 per cent. of the average run of school children have an actual IQ within six to nine points of that represented by their innate intelligence—that is, any changes in the ordinary conditions of life would not change the IQ more than six to nine points.

The California study, like others, supports the view that traits of personality and conduct are much more subject to influence from outside than are traits of intellect or physique. They represent social much more than biological aspects of life.

The three studies cited above give, for the first time, a scientific knowledge of some of the results of child adoption. They agree with common sense in showing that a child will do better with every assistance and sympathy than he will do with everything against him; they agree with the conclusion now widely accepted that the conduct of a child is something for which the parents themselves must take the responsibility—they can not blame their great-grandparents for it. But they all have the serious defect that they do not go much beyond the adolescence of the adopted child. What will happen when this child grows up?

Apart from the interests of society, which are a matter of eugenics, there are two interests to consider: that of the foster parents and that of the foster child.

(1) The foster parent desires a child to comfort his declining years; to bring the happiness into his life which only a child can bring. What chance has he to realize this hope by adopting one? As parents go, the chances appear from the New York study to be about even that the child will make him happy, or unhappy. Wise parents will do better than this; but not all parents are wise, especially when parenthood does not come to them until late in life, and then comes only in an artificial way.

The important points seem to be:

(a) To pick out a child with as good ancestry as possible. Bad as the ancestry of illegitimate children is, it has been pointed out above that it is likely to be better than that of legitimate children of the sort that are thrown on the market for adoption. The chief difficulty is that the ancestry is not so easily learned. But the mother is always known, save in the case of foundlings; and while she may conceal the paternity, either because she really does not know, or because she wants to protect the man, his identity can usually be ascertained with a little effort. A knowledge of the ancestry will tell what strong points the child is likely to have which can be developed, what weak points call for continual caution.

(b) The child should be taken young. Here again the illegitimate child has the advantage, for he can usually be gotten much younger than the legitimate child—many maternity hospitals make it a point not even to let the illegitimate mother see her child, if it is to be taken from her and brought up by others. An incidental advantage is that the real parents of an illegitimate child are less likely to make trouble, either for the child itself or for the foster parents, in future years, than are the parents of a legitimate child. One of the chief disadvantages of taking a child very young is that the presence of congenital syphilis is not quite so easily ruled out. Wassermann tests on the baby are not always dependable, nor are those on a pregnant woman, at least as ordinarily made. Here again a knowledge of the ancestry is a safeguard.

(c) The child should be taken only on trial. Many agencies have a fixed period of one year of probation before a child

can be adopted, and in some states a legal adoption may be voided at any time within five years, if desirable. This is a valuable provision for the protection of the child as well as the parents.

(2) The interests of the child are to get the best home possible, and to have the best possible chance in the world. It therefore makes less difference to him if he has to go through four or five homes to find the right one, even though he may have left broken hearts in the others.

On the other hand, it is possible for a child to have too good a home—not merely in the very common sense, in which he has life made too easy for him, as people often make it too easy for their own children; but in the sense that he has a better home than he can live up to. Almost any principal of a private school which receives the children of the leisure class can tell of the differences in ability between the foster children in the school and those "to the manor born." The latter are distinctly beyond the averages of their ages in brightness. The foster child represents a different ancestry; no matter how early he has been adopted and how carefully he has been schooled, he may not be able to make up the difference; he can not compete on even terms with those who started with a better endowment.

The result is that the foster children in such a group, though surrounded by every encouragement to succeed, contrast badly with their associates. They themselves feel this contrast more vividly than any one else, and a common result is the production of an inferiority complex, a feeling of baffled helplessness and resentment, which is likely to lead to a failure of mental adjustment.

Finally, it is not to the interests of the child to make a good marriage and produce defective children. He should at least be warned in this respect, even though the knowledge of the facts of his ancestry may cause pain. It is generally recognized by thoughtful students, I believe, that the child should not be allowed to grow up with the supposition that he is actually the offspring of his foster parents; that the fact of legal adoption, which Henry Maine called "the most violent of fictions," should not be converted into a real lie. The foster child faces in this respect a dilemma, both horns of which are certain to wound deeply. But it can not be escaped.

Any one who thinks eugenically will not want to see the lines of descent falsified by a concealed adoption, and such concealment will probably only store up trouble for the child in years to come.

By a favorable combination of circumstances, some of these children with defective heredity have themselves largely escaped the consequences. They are carrying genes of worse traits than those which are openly expressed in their minds and bodies. These will appear in their own descendants, to the great chagrin of all concerned. These children can not marry wisely in the future without knowing their own ancestry. They can not even avoid the possibility of incestuous matings; and although incest has no biological significance other than that of consanguineous marriage in general, the strong social tabu against it is based on cogent grounds. A young man who fell in love with Ninon de l'Enclos committed suicide when he learned that she was really his grandmother. To give him the benefit of the doubt, however, perhaps he killed himself not from chagrin at making love to an ancestor, but at having such an ancestor. Anyhow, for the child's own benefit as well as that of society, every effort should be made to get at the truth of the heredity, and this should not afterward be concealed or misrepresented.

A HYPOTHESIS OF POPULATION GROWTH

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In size a population varies directly with amelioration of the conditions of existence and inversely with the prevailing level of the standard of living. Here is a hypothesis of population growth expressed in two coordinate clauses. It suggests that a variable, "size of population," is controlled by two other variables, "wealth" and the "standard of living." Our prime variable, size of population, tends to move in the same direction as our second variable, wealth, and in a direction opposite to movements of the third variable, the prevailing standard of living.

The population problem has always been considered the peculiar province of the economist, probably because the lone classic on population was the work of a man who later became a professor of economics.[1] But the two most substantial modern works upon the subject were drawn from the experience of biologists, E. M. East and Raymond Pearl.[2]

The first clause of our hypothesis, "the size of a population varies directly with amelioration of the conditions of existence," has received for nearly a century the close scrutiny of biologists, and it has been generally considered exclusively their property. But the idea was borrowed, in the first place, by Charles Darwin from the work of Thomas Robert Malthus, who was a professor of economics at Haileybury College, England, from 1805 to 1834. "In October, 1838," says Darwin, "that is, fifteen months after I had begun my systematic inquiry, I happened to read for amusement 'Malthus on Population,' and being well prepared to appreciate the struggle for existence which everywhere goes on from long-continued observations of the habits of animals and plants, it at once struck me that under these circumstances favorable variations would tend to be preserved, and unfavorable ones to be destroyed. The result of this would be the formation of a new species. Here, then, I had at last got a theory by which to work."[3]

Although Darwin called his *magnum opus* the "Origin of Species," the thesis therein contained is not so much a theory of the origin of species as a theory of biologic progress. Modern biologists are not quite sure that the essential differences between a whale and a shark or even between a whale and a sea-lion ever could have been brought about by "variation" and "natural selection." The theory of accidents or sports has been inserted in a supplementary or even supersessive sense. Over-propagation with consequent premature destruction (in the main, selective) is retained, however, as a theory of the progress of individual species and as a theory of the general forward march of life. (The term, "forward march of life," has of course no moral significance; we mean simply adaptation to lodgment which seems to express itself mainly in progressive complexity of structure and concurrent

[1] T. R. Malthus, "An Essay on the Principle of Population," 6th ed. 1826.

[2] E. M. East, "Mankind at the Crossroads," 1923.

Raymond Pearl, "The Biology of Population Growth." 1925.

[3] "Life and Letters of Charles Darwin," edited by his son, Francis Darwin, 1883. Volume I, p. 83. In the opinion of E. M. East, Malthus in turn borrowed his idea from Franklin, who expressed the whole Malthusian principle in "three paragraphs." ("Mankind at the Crossroads," p. 46.)

functional specialization of cells. But a law of diminishing returns seems to come into play here, for mere multiplication of cell varieties on a functional basis can not solve all life problems and *in extremis* must defeat itself—multiple stomachs, and most vestigial forms, bear witness to this fact, although the most complex life form—usually called the highest life form—man, appears to carry off the palm for prevalence and persistence.)

In order to get movement into his hypothesis, Darwin was forced to accept Malthus's central doctrine, over-propagation.[4] Darwin had noted the two prime facts of biologic progress, heredity and variation, and he realized that these two were but the inert groundwork of development; but in over-propagation and consequent pinching out of the least-favored individuals he discovered a motor for his scheme.[5] Darwin's main thesis—that progress and species arise from propagation beyond the means of subsistence—has been importantly reshaped; but the fact of over-propagation, upon which his thesis rests, has stood up under the scrutiny of four generations of biologists. It is to-day one of the central axioms, theories, hypotheses, prejudices—call it what you will—of every biologist: *All life tends constantly to press upon the conditions of existence.* Collective life, everywhere and always, tends to exceed the warrant for it. And this is simply a converse statement of the first clause of our hypothesis: "The size of a population varies directly with amelioration of the conditions of existence."

But it is not the growth of population which needs explaining. The universal life-fact of over-propagation, coupled with an enormous and cumulative expansion in human well-being, amply justifies a far greater growth than any population has experienced. "Assuming a doubling in twenty-five-year periods to be well within the historic as well as the physiological limit, the descendants of a single pair living at the time of Christ would to-day be sufficiently numerous so that the entire surface of the earth would furnish standing room for about one eleventh of their number."[6] It is the slowness of population growth and the small size of present-day populations which want explaining. Here then is offered the possibility of an important economy of attention. We may concentrate mainly upon the second clause of our hypothesis: population tends to vary inversely with the prevailing level of the standard of living: our main task is to examine the proposition that the standard of living, in its complete bearing, explains the slowness of population growth.

In brief, the problem of population presents two sharp, clear questions: (1) Why do populations increase? (2) Why do they not increase more rapidly? We find that biologists have answered with unanimity the first question, offering propositions that are supported by a reassuring array of data. But students of population answer the second question with widely divergent opinions. Do the valid portions of all of these opinions find their ultimate explanation in the rising standard of living? Upon this quintessential putting of the question the main weight of our attention must fall.

Let us illustrate the salient features of our hypothesis with an imaginary instance from insect life and a few rough data of population and human well-being. A tiny colony of ants appears in a desk drawer. A few grains of sugar at tea time somehow fell there

[4] Wallace, as well, acknowledges his debt to Malthus; see A. M. Carr-Saunders, "The Population Problem," p. 18.

[5] A fuller statement of the theory of progress appears in a brief essay, "Progress—By Accident or Plan," by the present author, Scientific Monthly, 20: 159–162.

[6] E. B. Reuter, "Population Problems," pp. 115–16.

and attracted these immigrants. There was food in the region from which they came, but it was not so plentiful as in this new world. Just so has America become peopled with Europeans. An ant, let us say, requires for sustenance one grain of sugar a day. We supply, daily, exactly ten grains; the ant population soon will settle down to exactly ten. If there were originally thirteen ants, three must emigrate or die. There are precisely ten grains of sugar, and that will support ten ants—no more. The rate of propagation is a furious one. That matters not. Ants in other regions get wind of the sugar, and a terrific immigration sets in. Again, no matter. Immigration, emigration, death-rates, birth-rates—all are secondary considerations in the population problem; they are themselves determined mainly by economic circumstances. The controlling fact is the sugar supply, ten grains, that settles it: a population of ten, yesterday, to-day, forever.[7] . . . The population of Nevada per square mile amounts to seven tenths of a person. Nevada's meagerness will support no more. But Massachusetts' humming mill-wheels produce a flow of wealth that supports a population per square mile of four hundred and seventy-nine. More sugar, more ants.

In a burst of open-handedness, we raise the sugar-ration to twenty grains. A few weeks later we take a census—and with what result? To be sure: twenty ants. There was immigration, but no matter; the death-rate slackened; it is quite possible that even the birth-rate may have changed—biologists are not quite clear on that point—but no matter. There is but one point of import: twenty grains of sugar daily instead of ten. Ten grains: ten ants. Twenty grains: twenty ants.

For hundreds of generations, the population of North America (before Columbus) remained nearly stationary at a million and a half:[8] to-day, only four and a half centuries later, it is a hundred times as great. The vast wilderness for thousands of years yielded to bow and arrow sustenance enough for a million and a half of mankind—no more. Then forests were felled, making rich tillage and pasturage. Machinery came, and system, and science, opening richer fields: coal fields, oil fields, iron fields, copper fields, gold fields. A Niagara of wealth poured forth its abundance. Population increased a hundredfold. More grains of sugar: more ants.

Let us see how our little colony is getting on: Twenty grains of sugar, daily, and twenty ants. However absurd, let us say our ants demand a bird-shot each to roll about in play. No; our generosity will not afford so much. But as they insist we compromise on ten shot, and daily, ten grains of sugar. Ten grains of sugar and twenty ants? Yes, ten ants must die. A standard of living that includes both sustenance and play pinches out ten lives. High and unbalanced living-standards are as deadly as natural scarcities.

Cruelly high standards of living check the growth of population as effectively as ever did niggardly nature. In every modern community there are families possessing an automobile, whose children are not properly clothed, or nourished, or doctored. Dressed to look like bankers' sons, young men stand on street corners in winter smoking cigarettes to keep warm, because they have no money for woolen underwear and top coats.[9] Handsome coupés which flash through fashionable boulevards on pleas-

[7] This ant instance—and the material which follows—is not introduced of course to substantiate our thesis, but merely by way of illustration. A physicist exhibiting a model made of wire and wooden balls, representing the relative positions of the protons and electrons of a chlorine atom and their paths of motion, is not trying to prove a theory of matter, but simply endeavoring to illustrate a strongly appealing hypothesis.

[8] A. M. Carr-Saunders, "The Population Problem," p. 477.

[9] The illustrations contained in this paragraph are given more fully in "A Sponge

ant Sunday afternoons are not all occupied by rising young attorneys and plant managers, but often by a clerk from the department store or bank; and painfully, week by week, that clerk is paying something down to an automobile dealer as the price of his meretricious masquerade. At first glance, huge modern wealth seems to have lifted man above the reach of the iron claw of natural selection, but the burden of a towering standard of living bears him down. The family of the modern wage-earner whose wants and worries include theater tickets, a motor car, satin slippers and radio can afford little thought of physical examination or oculist or dentist. Twenty-five per cent. of the children in our large cities go to school every day badly nourished (in New York 34 per cent.), and the parents of many of them own motor cars, radio outfits, fur coats—at least, one of these luxuries.[10]

Had our colony of ants been content with five shot for play and fifteen grains of sugar, the population could have been maintained at fifteen. Had they insisted upon their shot and other gimcracks besides, driving us to cut the ration to five sugar grains, the surviving ants might have lived a well-equipped, civilized, sophisticated life; but survivors would number only five. Our example is absurd? It is not true to ant life? No, but true of man life, where interest is thus divided between desires and needs.

A wren, a mouse, a perch—every living thing but man—has a fixed standard of living; food every so often, crude shelter, perhaps, and nothing further. An increase in sustenance means a like increase in population. But man produces consciously a large part of the food values he consumes, and he insists upon producing and consuming other values as well. (The value of a motor-car, a rather handsome motor-car—that value, in food, would support a workman's family for seven years.) Man's productive energy is divided: part is expended upon the production of food values, and part upon the production of far different values: buildings and clothes, steamships and railways, theaters and parks, telephones and motion pictures, radios and motor-cars, smoking materials and chewing gum. In the proportion that these things enter into the standard of living, by just so much, the tendency of human population to increase as wealth increases is thwarted. Populations, whether of ants or wolves or butterflies or men, tend to increase directly as wealth (weal) increases; but when we speak particularly of man, we must add: population tends to decrease as the standard of living—and with it, the standard of craving—rises.

Though the annual flow of wealth in Great Britain more than equals the total wealth produced each year in China, the population of Great Britain is but forty million, and the population of China, perhaps four hundred million. A vast difference in living-standards explains this striking contrast: the Chinese standard of living is hardly a tenth as high as the British. The population of the United States is one hundred and twenty million; the population of India triples that amount, though India's rate of wealth production is not a third that of the United States. Again, a difference in living-standards will explain. If Americans were to convert into food values the huge flow of wealth which they create, contenting themselves with an East Indian standard of living, population would soon number half a billion —assuming, of course, a revolution in food-producing methods in the United States or in some dark continent with whom we might exchange our manu-

Theory of Population,'' by the present author, *The New Republic*, Vol. XLI, no. 527.

[10] E. B. Reuter, ''Population Problems,'' p. 255.

factured goods—and this assumption is not nearly so bold as the suggestion that an American be content with a standard of living cut a tenth its present dizzy height.

The amount of wealth produced annually in Montana is about equaled in Mississippi: but Mississippi has three times Montana's population. Simply, the standard of living in the southern black belt is very low. Standards of living on the other hand are about the same in Idaho and Kansas; yet Kansas' population is four times that of Idaho. And why? Kansas produces annually far more wealth than does Idaho. If the annual production of wealth in Great Britain increases by 10 per cent., but every family consumes 10 per cent. more in comforts or in luxuries, population must remain the same.[11]

Birth-rates, death-rates, immigration, emigration—all are secondary considerations in the population problem. The piston, piston-rod and crank-shaft of a steam engine are important, but secondary circumstances; the underlying matter is pressure and the expansive force of steam. Controlling factors in the growth of human populations are but two: the rate of wealth production and the standard of living.

Insect, animal, reptile and plant populations vary directly as the means of subsistence increase or decrease. These creatures are not hampered by intelligence and a craving for ever higher living-standards.[12] But with man it is different. In regions where similar living-standards prevail, population varies according to the amount of annually available wealth: in areas that produce equal amounts of wealth, population varies inversely with the height of living-standards.[13]

"What all strive for, even the poorest, is not a living but a way of living."[14] Here is an appealing view which is slowly pervading thought upon the problem of population. A shrewd London stock-broker, a Portuguese-Hebrew by descent, was probably the first person to appreciate in the slightest the bearing of the standard of living upon the size of populations. Says David Ricardo: "The friends of humanity can not but wish that in all countries the laboring classes should have a taste for comforts and enjoyments, and that they should be stimulated by all legal means in their exertions to procure them. *There can not be a better security against a superabundant population.*[15] In these countries where the laboring classes have the fewest wants, and are contented with the cheapest food, the people are exposed to the greatest vicissitudes and miseries."[16] The second clause of our hypothesis, which hazards the guess that population varies inversely with the prevailing standard of living, is simply an acknowledgment that these views are probably correct.

But the second clause of our hypothesis does not merely "emphasize" the standard of living; it asserts that the effect of the struggle for a higher standard of living includes and overreaches the force of the Malthusian checks upon the growth of population. The word

[11] The mathematical turn which our language takes at this point should not be construed as a statement of our hypothesis, but merely as a mathematical illustration of it.

[12] Cf. James Bonar, "Malthus and His Work," pp. 61–2. Cf. "Parallel Chapters from the First and Second Editions of Malthus' Essay on the Principles of Population" (Macmillan Co.), p. 13.

[13] The version of our hypothesis stated here is from a paper in the SCIENTIFIC MONTHLY, July, 1926, 24: 16–18.

[14] R. M. MacIver, University of Toronto, "Civilization and Population," *The New Republic*, December 2, 1925.

[15] Italics are ours.

[16] "Principles of Economics." Chapter V, 2nd edition, p. 95.

emphasized is quoted from an editorial review of the first published statement of our thesis.[17] If our first statement was open to misunderstanding, let us be clearer here. The modern struggle for higher and higher standards of living not only delays marriage and brings restriction of births, it also causes a disregard of the fundamental necessities of life. Not only are all swept into the mad race for civilization's alluring prizes, but the pace has become so furious and attention is so intently centered upon the non-essentials and luxuries of modern life that there is starvation in the midst of plenty. Many persons, whose wages should afford every physical necessity, go undernourished and badly clad to avail themselves of the distinction lent by the latest model this or that, or the elation and thrill to be had from the latest form, or pitch, of amusement. The desirability of a good quality of food and other essentials is by its obviousness thrust into some oubliette of consciousness; while luxuries, which are the more conspicuous for their rarity, are feverishly desired. Undernourishment, exposure and resulting disease are as definitely operative in checking the growth of population as when wealth was far less abundant.

In wording our hypothesis, have we used the term *wealth* correctly? Do we mean wealth or do we mean well-being? Population tends to increase directly with wealth, or, population tends to increase directly with well-being? There is an important difference in import—in part these terms are contradictory. Wealth is a smaller realm within the domain of well-being. Human wealth comprises all items of well-being that exist under scarcity conditions. A clear warrant certainly for our saying that these terms are in large sense contradictory, for only when an item in human well-being becomes inadequate—becomes scarce—is it classed as wealth. That area in the field of well-being not covered by the term wealth comprises items of well-being which do not exist under scarcity conditions, and which therefore can not constitute a limiting, or a controlling, circumstance. We have then chosen our language correctly: Population tends to vary directly with wealth. *Wealth* is our word.

Let us sum up. Over-propagation is universal. Life tends constantly to press upon the conditions of existence. Human life offers no exception. Wealth—all items of human well-being that exist under scarcity conditions—epitomizes the objective limiting circumstances of human existence. But the growth of population has not kept pace with amelioration of the conditions of human existence—population has not increased as fast as wealth. How are we to explain the *slowness* of population growth? The sole difference between the human case and all other cases in population is the progressive inclusion of non-essentials in a rapidly rising standard of living: wealth multiplies rapidly, but it is split into constantly larger shares: a certain increase in wealth therefore does not result in proportionate increase of population. *Marriage is delayed and births are restricted;* furthermore, emphasis is thrown upon non-essential values, and the simple necessities of life are neglected; undernourishment, exposure and resultant disease are consequently kept in play. A rising standard of living—and standard of craving—trims population at both ends: it tends to reduce the birth-rate and works against the reduction of the death-rate. Our hypothesis of the growth of human population therefore should be read: ***Population tends to increase directly with wealth, and inversely with the prevailing level of the standard of living.***

[17] New York *Times*, January 7, 1925, p. 24.

DEAD VERSUS LIVING MEN

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Professor Huxley, while insisting on the demonstrable structural similarity between the anthropoid apes and man, maintained that the differences between them are great and significant, and that the relatively slight physical differences are emphasized by the relatively enormous differences in habits and mode of life. He was unwilling to view man simply as a corpse, believing that a true picture of man in his relation to the animal world could be obtained only by giving due consideration to all available comparative characters, both structural and psychological.

But Sir William Flower was strongly antagonistic to this point of view. He maintained that in considering the relationships between man and the animal world the same principles of classification must be used as are applied elsewhere, because zoological classification never has taken into consideration the psychological characteristics which distinguish the subjects of its investigations. He said further that the essential attributes which distinguish man and which give him a perfectly isolated position among living creatures are not to be found in his bodily structure and therefore should either be left entirely out of consideration or have such weight given to them as would remove him completely out of the region of zoological classification. His position was that to profess to classify man as if he were one of the animals, as in all points of the structure and functions of his organs he undoubtedly is, to place him in the class Mammalia and then to allow other considerations to influence our judgment as to the particular position he should occupy is most illogical.

Since Professor Huxley's time the broader concept of man has among biologists been completely superseded by the narrow view-point so well enunciated by Professor Flower.

This narrow view-point has been developed in such a way and to such extremes as to lead to conclusions which in their total disregard of man as man can not but give offense and arouse antagonism.

No one can deny that a detailed comparative knowledge of the structure of any creature is essential to the determination of its position in relation to the other animals.

But those who study animals both in the field and in the laboratory soon become aware of the important fact that no animal form can be properly understood from the facts revealed by the study of its structure and anatomy alone. An animal is something more than the sum total of the organic compounds, the secretions and the deposits that make up its body. There is something in addition to the tangible physical complex represented by its structure and anatomy.

The bodily mechanism of every animal in life is operated and controlled by a mental mechanism which as yet we are unable to explain in terms of physics and of chemistry. In each sort or kind of animal this mental mechanism takes the form of a definite complex peculiar to the species.

These mental complexes are as much a part of the individuality of each species as are the tangible structures of the body. To base our conclusions upon a single set of characters and to dismiss others as irrelevant is simply to confess

our inability to comprehend and to interpret the whole in its true relations.

It sometimes happens that two animal forms when studied as museum specimens are so extremely similar as to be scarcely separable, or even not always separable with certainty, although in life they could not be confused. For instance, when I was living on the island of St. Vincent I was very familiar with two little flycatchers which have quite different habits and a different song. One is found only in little companies in the lowlands in the vicinity of Kingstown, while the other is solitary and lives on the mountain sides. Must we regard these as trivial varieties of the same species, which is the only course possible on the basis of museum material, or shall we take into account the obvious and considerable differences in their habits and their songs and call them different species?

Descriptions of the different breeds of dogs would be considered wholly incomplete without some mention of the mental traits of each. This is because we appraise the dogs on the basis of all the characters which enter into their relations with us. The diverse mental traits of the different breeds, therefore, become a matter of great interest.

But if in the case of dogs we are always careful to consider the mental differences as well as the structural variations more or less peculiar to each of the several breeds, why should we not admit that the habits of all animals should in the same way be considered in connection with their structure? Why should we be so careful as to emphasize the terriers' peculiar propensity for digging, the spaniels' curious love for water and occasional dexterity in catching fish, the stupidity and ferocity of bull-dogs, and all the other canine traits, and then maintain that man in his relation to the apes must be considered wholly, or almost wholly, on the basis of his structure?

How can we acknowledge the importance of the mental differences between the greyhounds and the hounds, between both of these and collies and between all three and bull-dogs, and then deny, or at least minimize, the importance of the mental differences between the orangs and the chimpanzees, between both and the gorillas and between all these and man?

So far as our evidence goes, the use of fire and of tools were human attributes from the very first appearance of mankind. It may be assumed that the same is true of speech and the use of clothing. There is not the slightest evidence that these human attributes were acquired one by one as man departed more and more from an ape-like ancestor.

It so happens that the closest parallel to the activities of man is to be found in the activities of the insects and their allies and not among the vertebrates or backboned animals where we should expect to find it. Furthermore, among the vertebrates the birds as a whole come rather nearer to man in the scope of their mental attributes than do the other mammals, while among the mammals the rodents—rats, mice, beavers and their relatives—are the most similar.

The use of fire and of fashioned tools is confined to man. Certain ants, some reptiles, as the alligator, and certain of those strange birds called megapodes make use of artificial heat of bacterial origin derived from decaying vegetation. But the ignition point is never reached.

Certain digger wasps use little pebbles or little bits of stick to smooth the earth down over a buried victim. The spinning ants build their silk nests by using their grubs which they hold in their jaws and pass back and forth from leaf to leaf. The grubs have silk glands which the adults lack, so that the construction

of silken nests by ants is possible only through a curious system of enforced child labor. There are other cases of the use of tools and implements by insects. But the tools they use are never made by them.

Many insects in their early stages encase their body in a little jacket made of various substances bound together with a web of silken threads. For instance, the caterpillars of the clothes-moths make suits for themselves of hairs cut from ours. The larvae of the caddis-flies make somewhat similar covering out of sticks or sand grains. Very many insects construct an elaborate cocoon, which may be waterproofed inside, wherein the pupal stage is passed.

Many youthful insects cover themselves with the empty skins of their victims or with various foreign substances which they impale upon or entangle among their spines. This may be primarily for the purpose of concealment or deception, but in many cases it seems to be simply for adornment. At any rate, the larva of a lace-winged fly or the caterpillar of an aphid-feeding butterfly draped in dead aphid skins strongly suggests a primitive human draped in furs.

Many insects have highly developed social systems which superficially seem much like those of man, as we see among the ants, wasps, bees and termites. Some of these social insects seem to be able to exchange a considerable range of information, though on principles quite different from human speech.

Some social ants make use of slaves. Others have developed an elaborate form of agriculture. Many make use of other types of insects—aphids, coccids, jassids, membracids and the caterpillars of various lycaenid butterflies—much as we make use of cattle. These they sometimes tend with the very greatest care, building shelters over them or looking after them in various ways and protecting them from their enemies.

Some insects make use of others which are much more powerful than themselves in traveling from place to place. For instance, the young of the oil beetles are transported by the parents or the attendants of their victims.

All insect societies support scavengers and also parasites of various types, most curious of which are other insects which persuade their hosts to feed them.

Chemical processes are extensively used by insects. These are, however, almost entirely concerned with special bodily secretions. There are the various types of silk produced by insect larvae and by spiders; the paper made by wasps; the wax produced by bees, aphids and other insects; sweet substances secreted by aphids and other types; narcotics used to stupefy the prey; antiseptic substances used to protect the eggs, and various kinds of poisons.

But here we become involved with the chief difference, other than structural, between the insects and the vertebrates. In their relations to the world about them the insects are mainly guided by the chemical senses which in us are represented by taste and smell, whereas in the vertebrates the eyes and ears are commonly the main controlling organs, often combined with touch, and smell and taste are relatively unimportant. So the extensive use of chemical processes by insects is quite in line with the largely chemical nature of their external contacts.

The very diverse snares of spiders and of some insect larvae, as the young of some fungus gnats, the various structures—nests, pitfalls, cells and others—built by insects and their often highly complicated tunnelings show an engineering skill and a knowledge of many of the laws of physics which is quite extraordinary.

Among the insects and their relatives each species on issuing from the egg and on entering every stage thereafter is endowed with a knowledge of all branches of science which is detailed and complete so far as concerns its needs at that particular time. At different periods of its existence its knowledge may differ widely, as in the case of those little caterpillars which at first are flower feeders, then enter ant nests and feed on the young ants and finally turn into butterflies, crawl out of the ant nest and fly away.

The only birds to make use of artificial heat are some of the megapodes or brush-turkeys. These scratch together a loose mound of leaves, rubbish and earth, lay their eggs in it and then cover them. The heat arising from the decaying vegetation in this natural incubator furnishes the warmth necessary for the hatching of the eggs. The same procedure is followed by the alligators and the crocodiles. Other kinds of megapodes and the crocodile bird of northern Africa simply bury their eggs in warm sand, like turtles.

In the formation of their nests birds display the most extraordinary skill in the use of fibers, sticks and mud, or in some cases the secretions from their salivary glands. They also show great skill in hewing out holes in the trunks and branches of dead trees, and in burrowing in banks and in the ground. Often extraordinary ingenuity is exhibited in selecting situations for the nests, both when they do the work of making them themselves and when they appropriate the deserted nest or nesting site of some other species. Many nests are very complicated, especially such nests as are entered from the side. Among the most curious are the ingeniously sewn nests of the oriental tailor-birds, the long pendent nests of the cassiques, related to our orioles, and the more or less similar nests of some of the African weaver-birds. Some birds, as certain weaver-birds and a small parrot in Argentina, build community nests, like apartment houses.

Some water-birds build floating nests, like rafts, which may be towed from place to place. The motmots build their nests in the nests of termites, and certain kingfishers in southeastern Asia make their nests in the holes of trees which are tenanted by bees.

Many birds ornament their nests. The common orioles often weave into their pendent nests bits of bright-colored yarn or string; the indigo bird incorporates bits of paper; the crested flycatchers use the cast skins of snakes, and other birds use other objects, such as shells or bright bits of stone or pebbles. One bird in India enlivens the vicinity of its nest with fireflies stuck in the ground.

But it is not only in the formation of their nests that birds show mental traits more or less parallel to those of man. The bower-birds of Australia build curious runs or play-houses which they ornament with bright and conspicuous objects of all sorts and which have no connection with their nests. Many other birds, particularly in the crow family, as ravens, crows, magpies and jays, are very fond of gathering and hoarding bright, conspicuous objects, especially metallic ones. It may perhaps be mentioned that many birds, especially among the parrots, crows and mynahs, can duplicate more or less extensively and correctly the sounds, though not the intent, of human speech. They are the only creatures which are able to do this.

Among the mammals, only the rodents can be compared with birds in the diversity of their mental traits. It may be noticed that all the true rodents have the peculiarity of sitting erect and using their fore paws very much like hands.

Many make rather elaborate nests on or in the ground, in grass or rushes, or among the branches or in holes in trees. The nests of rodents are always entered from the side or from below and are never open above like the nests of many birds. Perhaps the most interesting of the peculiarities of rodents is to be found in the construction of dams by beavers. Another interesting thing is the habit of some types, as the wood-rats and the Norway rat, of accumulating bright, conspicuous objects more or less after the fashion of the crows.

The existence in man, in the insects, in the birds and in the rodents of so many strikingly similar mental traits which are conspicuously absent in the monkeys and the other mammals must have some significance. There must be some basic underlying reason for this curious distribution of corresponding mental attributes. What have these various groups in common wherein they differ from the other creatures inhabiting the land?

Among the insects man-like mental attributes are almost exclusively confined to types in which the young are very different from the adults, either soft, delicate and headless grubs, as in the case of the ants, bees and social, parasitic and predaceous wasps—the mud-daubers, caterpillar-wasps and others—or soft-bodied, worm-like things as the young of caddis-flies and the caterpillars of small, feeble moths and butterflies. But they also occur in the white ants or termites, which are weak and feeble in all stages, and in a few other types. What may be considered the clothing of the insect body—the construction about it of a more or less dense cocoon of silk, of itself alone or used as a binder for other substances—is common to nearly all insects which have an inactive pupal stage.

Among the birds, mental attributes which parallel the human are almost exclusively confined to those types with helpless young which for their upbringing require the attentions of both parents, and among these they are most obvious and marked in the smaller and weaker forms. Birds with active and more or less self-reliant young which are tended by one parent only, large and powerful birds and sea-birds nesting where they are safe from enemies, as a rule show little or no skill in making nests and scorn the use of ornaments.

Weak and helpless young are especially characteristic of the rodents, particularly of the small mouse-like or rat-like rodents in which the man-like mental attributes are particularly to be remarked. The nests of rodents, like the nests of birds, are primarily incubators designed to facilitate the maintenance of a proper temperature. Many rodent nests, as those of various mice, the musk-rats and the squirrels, would seem to be constructed in such a fashion as to create within them through bacterial action a temperature higher than that outside. Whereas among the birds nests are used only for the rearing of the young, many northern rodents pass the winter in them in a state of hibernation.

So a survey of the animal world brings out the extraordinary fact that mental ingenuity is developed to offset some dangerous physical weakness in the animals involved. This physical weakness usually has to do with helpless younger stages, as in the social insects and the birds and rodents, but it may involve the later stages, as the helpless, inactive pupal stage of certain insects, all stages in the termites, and the hibernation period of rodents.

Thus physical weakness in the animal world is offset by the appearance of mental attributes comparable, or at least parallel, to those of man, and the more pronounced the weakness the more man-like do these attributes become.

Have these sporadic and isolated instances of mentality in the insects, birds and rodents any real bearing on the question of the relationships of man?

So far as his structure goes, man is extremely close to the anthropoid apes. There is no denying this. Those who insist on contemplating man solely as a corpse will stop right here. But those who agree with me that in order correctly and properly to understand man in his relation to the living world we must take into account the mental mechanism that controls and guides his body will wish to continue further.

Of the animal world taken as a whole it may be truly said that where the greatest weakness lies, there also lies the greatest strength. No one can deny that at the present time the insects are the most formidable competitors of man. There are more than three times as many different kinds of insects as there are of all other types of animals together. Among the insects by far the most numerous both in species and in individuals are those forms, as the ants, bees, wasps and their allies, beetles, flies and moths, which have weak and feeble worm-like young. They are the most successful and resourceful of the insects. They include the largest as well as the smallest species, but their average size is considerably less than that of other insects.

Among the mammals the dominant type at the present day is the group of rodents, especially the murine or rat-like rodents. Here again we find as the dominant group, most numerous both in species and in individuals, a group including species of which the average size is very small and which have helpless young.

Among the birds the dominant types, most numerous in species and in individuals, are again those of small size with helpless young.

So everywhere we find as the dominant types of animal life, at least on land, those with inherent weaknesses—small feeble bodies and dependent helpless young—which we might assume would imperil their existence. But in these types weakness of body is more than offset by the occurrence of more or less man-like mental alertness and ingenuity. In these types we see foreshadowed here and there, appearing in a curiously disconnected, sporadic and isolated manner, many of the mental attributes of man.

We learn from the study of paleontology that as animal forms increase in size or otherwise become increasingly more and more specialized they become less and less susceptible of change and more and more dependent upon the maintenance of conditions as they are. If conditions change, the giants and the highly specialized creatures disappear and the groups persist through the smaller and more generalized among the included types.

What bearing has all this on the question of the relationships of man?

First of all, let us repeat that man in his structure undeniably is extremely close to the anthropoid or man-like apes. At the same time there are sharp and clean-cut differences between man and any of the apes. Every bone in the body of a man may be at once distinguished from the corresponding bone in the body of any of the apes.

From the physical view-point man is the least efficient of all living creatures. In the first place, his young are helpless for many years and require parental guidance almost to the adult stage.

In the second place, man is the only vertebrate which has a serial family composed of dependent young in all stages of development ranging from newly born to adult or subadult. In all other vertebrates the young, whether as individuals

or in a litter, are always independent of the parents before new young are born. The only parallel to the conditions found in man are the serial broods of the social ants, bees and wasps. In the third place, man lacks the muscular power of the other vertebrates with which he must compete. His feeble body is no match for the powerful bodies of the great grass-feeding mammals or for those of the great cats, wolves and other predaceous creatures. He is relatively slow of foot and is a poor and inexpert climber.

Feeble and frail of body with helpless and dependent young and the further handicap of a serial family, man is the dominant living creature in the world to-day by virtue of his extraordinary mental attributes. These include all those found in all other living things and many more besides. Man must have a mind superior to that of all other living things because he has the maximum number of liabilities to meet.

It is commonly asserted that while the reactions of man are the result of intelligence, those of insects, birds and rodents are due to instinct, and therefore that the two are not comparable. Instinct is defined as "a special innate propensity, in any organized being, but more especially in the lower animals, producing effects which appear to be those of reason and knowledge, but which transcend the general intelligence or experience of the creature." In the Century Dictionary we read further that "instinct is said to be blind—that is, either the end is not consciously recognized by the animal, or the connection of the means with the end is not understood." Intelligence is defined as "discernment or understanding," and as "cultivated understanding."

Now if intelligence is really discernment or understanding, as according to definition it is, it is difficult to see wherein it differs from instinct as displayed by insects, birds and rodents. For instance, the caterpillar and other fossorial wasps display great discernment and understanding in providing for the welfare of their young, which they will never see. Their actions are certainly based upon definite and detailed knowledge of the conditions which must be met. How they acquired that knowledge is wholly unknown to us, but it is indubitable that the knowledge is there. Whether there is reason back of them or not is a matter of opinion. Reason is variously defined, but all definitions of reason are based upon the general idea that reason is a faculty characteristic of and peculiar to man. As a comparative term, therefore, the word reason is quite without meaning. Whether their actions transcend their general intelligence or experience we do not know. We have no measure whatsoever of their general intelligence, and we can not tell how much they may or may not remember from their own larval life.

There is no object in prolonging this discussion. On examining the facts we see that intelligence and reason are supposed to be peculiar to man; actions which in man are acknowledged to be the result of intelligence and reason, such as the use of heat, tools and clothing, if duplicated in insects are assumed to be the result of blind instinct. But in the absence of indubitable proof the same or very similar actions can not be supposed to arise from wholly different causes. So after all we are forced to admit that intelligence and reason are simply mental attributes we think we understand, while instinct is a mental attribute we know we do not understand. That seems to be the only tangible difference between them.

We marvel at the fact that every insect at birth and at the beginning of every subsequent stage thereafter is en-

dowed with a technical education which is entirely sufficient for its needs. This is instinct, we say. Then, putting all ideas of instinct aside, we carefully note the actions of an ape and compare them with those of a child. We find various similarities. Of course we do; it would be quite extraordinary if we did not. Some observers, closing their eyes to a whole series of important facts, say that this proves the close relationship between the apes and man. This relationship is already proved by their structure, so this is nothing new.

But we are not informed that none of the apes or monkeys have a true baby stage, except possibly of the briefest duration. They are born with what might be called a subadult mentality. The actions of the young are almost from the very first more or less like those of the parents. This is not at all the case with children.

In order to show the fundamental and far-reaching differences between babies and young monkeys three peculiarities of babies may be mentioned.

When babies begin to hold and to touch objects they show an extraordinary preference for hard and especially rough objects. Babies are very fond of passing their fingers over sandpaper, which they much prefer to ordinary paper. So far as I know this is not at all true of young monkeys.

Babies when playing with a hard object, such as a watch, always end by whacking it against something. If monkeys lose interest in anything they simply drop it. It may be remarked, however, that adult monkeys, especially baboons, are sometimes extremely destructive. The whacking propensity of babies certainly is not learned from their parents. It commonly results in parental resentment. But it is perhaps the most important and significant instinctive reaction of babies. It at once proclaims them as fundamentally different from monkeys. So does their preference for hard, rough objects. It is probably not too much to say that these two instinctive reactions of babies lie at the base of all material human progress.

A third peculiarity of babies is a constant desire to hold something. Young monkeys, of course, like to cling to the mother, but show no desire to hold foreign objects. This curious desire to have something in the hand is continued throughout life. Women prefer carrying valuables in hand-bags which are easily mislaid to carrying them in pockets where they would be safe and both hands would be free, and very many men feel more or less ill at ease without a cane or newspaper or something else carried in the hand.

It is usually assumed that man is descended from tree-living or arboreal apes. Every zoologist will admit that the apes and monkeys are very highly specialized.

From a study of paleontology we learn that a specialized type of creature either becomes still further specialized or dies out. It never gives rise to less specialized types. It is the least specialized creatures that contain the seeds of the evolutionary trees.

Now if apes and monkeys are highly specialized how could man have descended from them without forming a conspicuous exception to an otherwise fixed and immutable evolutionary law?

Nearly all modern evolutionists maintain that monkeys are primarily tree-living creatures. There is no proof of this whatever. Of course the great majority of the existing monkeys live in trees. But this does not prove monkeys as a whole to be, or rather to have been, fundamentally arboreal animals.

At the present day many kinds of baboons live where there are no trees,

while others, and also some of the macaques, living in sparse or open forests, prefer the ground to the trees. In a rather open forest I once surprised a Barbary ape feeding on the ground which made off through the woods at a terrific rate toward a rocky hill in the distance. Evidently it felt quite safe in the open, but not in a tree. In fact, this monkey and some of its relatives are seldom seen in trees, except when raiding fruit in the early morning.

Another very prevalent idea is that monkeys are primarily tropical creatures adapted to a warm climate. Most of the living monkeys are tropical. But the monkeys of the mountains of Japan, and especially those of the highlands of Tibet, are perfectly well able to endure extremely severe winters. Monkeys will live wherever there is a sufficiency of the right kind of food, regardless of temperature.

Monkeys can be properly appreciated only when considered in connection with the sloths and ant-eaters. The three types of living sloths all live in trees, hanging upside down from the branches. One of the ant-eaters, the well-known great ant-eater, lives on the ground, but all the other ant-eaters are exclusively, or at least chiefly, arboreal.

The sloths and ant-eaters, therefore, at the present time are more emphatically tree-living creatures than are the monkeys. The great ant-eater, like the chimpanzee and the gorilla, seems to have descended from the trees to the ground. He is very poorly adapted for terrestrial existence, for his fore paws are fitted for clinging and tearing, not for walking, and when he walks he supports himself on the knuckles of the fore paws with the fingers turned in just as do the gorilla and the chimpanzee. When cornered he does not make any attempt to run, because his awkward hobbling gait can not be quickened into an effective run. So he faces the enemy and stands erect with his long arms outstretched. The gorilla also faces the enemy, pounding his chest.

It so happens that we know a rather large number of fossil sloths. These are creatures which might be described as combining the body of the great anteater with the head of a sloth. They all had grasping fore feet with long claws and in walking the outer side of the wrist was placed on the ground, and the hand was turned inward.

The ground sloths were far too large and heavy ever to have lived in trees. But the structure of their feet, especially of their fore feet, was such as to make them especially well fitted for climbing, just as in the case of the monkeys. So some of the sloths became arboreal. Eventually all of them except for three small, tree-living types died out.

I can not help believing that the monkeys and the sloths must have had approximately the same history. The monkeys were probably originally terrestrial creatures with grasping fore feet but less specialized hind feet. As in the case of sloths and ant-eaters, tree-living forms were developed reaching their highest perfection in the gibbons and some of the American monkeys—especially in America. It is doubtful if the gorilla and the chimpanzee were ever more arboreal than they are now. While this is pure speculation, it is more reasonable than the assumption that monkeys are fundamentally tree-living creatures.

Man is, of course, one of the Primates, the group which includes man and the monkeys. He is structurally very close to the anthropoid apes, but there are definite, clean-cut and important differences between man and any of the apes. These structural differences are greatly accentuated by other differences which seem to be of a fundamental nature.

The young of man are helpless and pass a considerable time in a baby stage, whereas the young of all monkeys are practically from the first little monkeys. Many instinctive reactions of babies are related to distinctive human traits and are very different from anything seen in young monkeys.

Man has a serial family of more or less helpless young in all stages necessitating the combined care of both parents, or its equivalent, over a long period of years. The serial family is the basis of the human social system, which is wholly different from the horde life of the apes.

Elsewhere in the animal kingdom a serial family of dependent young is found only in the social ants, wasps and bees, which have as a result developed a social system parallel to the human. In the monkeys we find a social life without any social system. The individuals simply live together in a promiscuous horde in which each female raises her own young unaided. The social life of monkeys resembles that of wolves, wild cattle and other creatures, but not that of man.

Man is physically weaker than any of his competitors. But this weakness, accentuated by the dependent family consisting of several or many children in all stages of development, is offset by the existence in man of inherent instincts—foreshadowed here and there in isolated instances in the lower animals but grouped and accentuated in man—such as the use of fashioned tools, of fire, of speech and of clothing.

These inherent instincts have by man himself been coordinated into intelligence, and this intelligence developed until now man is easily supreme. Not only has man been able to excel all other living creatures in their specialties, including rapid transportation over the land and over and through water, flying and burrowing, but he is rapidly mastering the mysteries of the chemical syntheses of plants.

Man never was arboreal, and none of his ancestors was ever arboreal. All his characteristics are those of a ground-living creature walking erect. Man never was a monkey. Man is a mutation, and a rather broad mutation, from the same general stock as that which produced the monkeys. Just what that was we do not know.

A BIOLOGICAL METHOD FOR DESTROYING BEDBUGS

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SEVERAL preparations of known and unknown composition have been tried for the destruction of bedbugs. The results from the use of these preparations, however, are irregular and incomplete. They require persistent use of antiseptic medicines on the spots requiring disinfection—a task and expense varying according to the size of the place to be disinfected.

To-day the proposed method is not limited to the use of antiseptic drugs only. It is a biological method involving no great additional work or expense.

The bedbugs, as we know, belong to the class of semi-winged, of the family of Cimicids, with the name *Cimex lectularius* for the bedbugs of our country, *Cimex rotundatus* for tropical bedbugs, *Cimex hirundinis* for bedbugs of swallows' nests. Several writers have stated that bedbugs are carriers of different diseases, chief of which are: recurrent fever, plague, leprosy, tuberculosis, kala-azar and the American trypanosomiasis; but for the present these remain simply as conjectures until further investigations show whether they are well founded or not. July, 1925, H. E. Shortt and C. S. Swaminath[1] pointed out that bedbugs could not transmit kala-azar to monkeys, although the parasites developed enough in the body of the bedbugs on which they were making their experiments. Disregarding the diseases mentioned above, the nightly disturbance of the parasites is such that many have experienced their bites, especially if one happened to be in a small country hotel or has been in military service. From many people who have come to Greece to study and see the ancient monuments I have heard complaints because of the bites which they have received in various Greek towns. My friend, Stilpon Pittakis, director of the late Museum of the Evangelical College of Smyrna, came to me in desperation, after a sleepless night, and in reply to my question as to the reason for his condition said, "Athens was called famous by the ancients; I call it a city of bedbugs, *Koreopolis.*"

The condition of some of the houses of modern Greece as well as of Albania and other parts of the Balkans has been the same from antiquity. In the "Clouds" of Aristophanes we read this interesting dialogue:

> Socrates: Here Strepsiades, bring me a bed.
> Strepsiades: But I can't. The bedbugs won't let me.

In the "Frogs" of the same author, Dionysus asks Heracles, when he was thinking of going to heaven, "Tell me about it—ports . . . streets, hotels, where bedbugs are most scarce."

In Athens in September, 1922, after the tragic days of our nation, many refugees were established in wooden barracks. Immediately bedbugs were found to such an extent that many of the inhabitants spent the night in destroying these parasites. Unfortunately, the bedbugs multiplied so rapidly that in 1923 many inhabitants of the camp "Kaisariani" during the summer nights moved their beds into the roads or into neighboring fields in the hope of finding a few hours of rest. Unhappily even this was impossible because the bedbugs came

[1] H. E. Shortt and C. S. Swaminath, *Indian Jrl. Med. Research*, July, 1925, 143.

down from the roofs of the camp into the roads and quickly reached the beds of the people; and after a time some members of the family were forced to sweep the floor in order in this way to keep an area clean from the approaching army of bedbugs. This I could not verify myself, but trustworthy inhabitants of the camps reported this state of affairs on several occasions. Such was the condition for two years, 1923, 1924. Then suddenly the bedbugs decreased and gradually disappeared completely, first in the camp "Kaisariani" and then in the others. Probably some thought that this result was due to the cleaning which the inhabitants had undertaken, for they had worked very hard to clean their rooms, using different antiseptics. But we know that disinfection of the wood from such parasites is practically impossible, especially in these wooden barracks where some people succeeded in destroying the parasites, but others, for various reasons, through carelessness or inability to use antiseptic medicines, did not meet with any effective result.

The destruction of the bedbugs came finally and completely, because they were no longer found after 1925 in the camps mentioned above. We examined the various causes, and finally found a special kind of spider which we studied intensively in the laboratory of the American Near East Relief. This is the reason for the destruction of the bedbugs. This spider is in length about one and a half centimeters, in width three quarters of a centimeter, and is made up of the cephalothorax, abdomen and four pairs of legs. It is of light gray color, the dorsal surface of brown with three bands of darker color, one in the middle and one each on the sides, all three curving down to the abdomen.

The movements of this spider are such that one is amazed at the ease with which it seizes not only bedbugs but also flies that happen to fly near it. It feeds especially on the blood of bedbugs, seizing the insects by their backs and sucking their blood to such an extent that finally there is nothing left but the skin.

The bedbug does not appear to be aware of such a dangerous enemy, because it draws near to the spider without fear, and we know, on the contrary, that it tries to save itself when it is pursued by man. When a bedbug draws near to the spider which is already busy with its first prey the spider pricks the second bedbug with its hind legs so that it remains motionless until the spider has finished its first victim. I thought that through these pricks the spider anesthetized its prey by some special kind of poison, but my friend, Mr. Tanagras, to whom I mentioned the actions of the spider, explained this by the phenomenon of catalepsy.

In this way each spider in our laboratory fed upon thirty or forty bedbugs a day, according to their size and to the quantity of blood food. After a few days the female formed a nest of solid, narrow web, about four centimeters square, within which there were found thirty yellow eggs, of the size of the head of a pin. When examined with a microscope they are seen to be disk-shaped, and have a central nucleus of thick, gray matter, while the circular part around it is transparent. After eighteen days the young spiders are hatched in the summer time, and immediately they begin to attack the bedbugs with no fear of their large size, curiously enough. Several young spiders attack the bedbugs upon their backs and suck their blood in the same way as the adult spiders do. Their development takes place quickly, and in about three months they reach a fully mature form, after which they will change their skins several times.

The same spider weaves two or three nests in summer time, and watches over them during the incubation period. I

sent some specimens of this spider to the British Museum of Natural History for further study. To Dr. Louis Sambon, who very courteously examined my specimens and sent me detailed information concerning them and the pitting of natural enemies against carriers of diseases during ancient times, I owe very deep obligations.[2] Dr. Sambon determined that the bedbug-eating spiders belong to the genus Thanatos, subfamily Philodrominae of the family Thomisidae. I sent specimens to Dr. L. O. Howard, the famous entomologist of Washington, D. C., and at his request Dr. Petrunkevitch, of Yale University, very kindly determined the species as *T. flavidus* Simon.

So far as I am aware there is no record in entomological or medical literature of spiders being used to eradicate bedbugs. Dr. Sambon wrote to me:

> Your information concerning the destruction of bedbugs by spiders in the infected wooden barracks allotted to refugees in Athens is of great interest and parallels an observation I made some years ago (1910) in Italy, where in stables of the Province of Bergamo I found similar spiders, preying upon swarms of the stable-fly (*Stomoxys calcitrans*) gorged with the blood of oxen. From time immemorial the Italian peasants have held that cobwebs in stables are essential to the healthiness of cattle and my observations proved them right.[3]

The bedbug-eating spider, although named *Thanatos*, is not poisonous, for the refugees never reported to me any trouble, pain or poisoning due to the spiders. Spiders of the group of Philodrominae are of world-wide distribution and very ancient, as fossil specimens have been found in amber. These active araneids are found usually on grasses, bushes or trees. They probably came to the camps from the neighboring small woods.

Various insects have been mentioned as effective enemies of the bedbug, and their artificial introduction has been suggested as a possible means of control. Among these I may mention the common "kissing or assassin bug" (*Opsicoetes personatus*), the house cockroaches (*Blatta orientalis* and *Blatella germanica*) and the house-ants, especially the tiny red ant (*Monomorium pharaonis*).

Opsicoetes (*Reduvius*) *personatus* was well known to Linnaeus, who wrote "Consumit Cimices Lectularius huius larva, horrida personata." With regard to the cockroach one writer says:

> Previous to our arrival here (St. Helena) in the *Chanticleer*, we had suffered great inconvenience from bedbugs, but the cockroaches no sooner made their appearance than the bugs entirely disappeared. The fact is that the cockroach preys upon them and leaves no vestige or sign of where they have been. So that it is a most valuable insect. . . .[4]

Concerning the little red ant, C. L. Marlatt, of the U. S. Department of Agriculture (1896), writes:

> Mr. Theo. Pergande, of this office, informs me that during the late war, when he was with the Union army, he occupied at one time barracks at Meridian, Mississippi, which had been abandoned by the southern troops some time before. The premises proved to be swarming with bedbugs; but very shortly afterwards the little red house ant discovered the presence of the bedbugs and came in enormous numbers, and Mr. Pergande witnessed the very interesting and pleasing sight of the bedbugs being dismembered or carried away bodily by these very minute ants, many times smaller than the bedbugs which they were handling so successfully. The result was that in a single day the bedbug nuisance was completely abated. And Mr. F. O. M. Boggess from Florida heartily recommends the artificial introduction of the ants to abate this bug nuisance.

Assassin bugs, cockroaches and red ants can hardly be considered as practical factors; Dr. Sambon says that they are as undesirable as the bedbug itself.

[2] L. Sambon, *Jrl. Tropical Medicine*, June, 1924; "Observations and Researches on the Epidemiology of Cancer made in Holland and Italy (May-September, 1925)," August, 1926; "Tropical and Subtropical Diseases," *Journ. Medicine and Hygiene*, June, 1922.

[3] See "Progress Report on the Investigation of Pellagra," *Journal of Trop. Med. and Hyg.*, London, 1910.

[4] Foster's "Voyage," Vol. I, p. 373.

But we can not say the same thing for the spider of the refugee camp, which is not poisonous. These spiders cleaned all the camps at Athens without any other expense. Therefore, I think that their artificial introduction, in military barracks, old houses and in some of the hotels of the Balkans, is to be recommended.

The biological method of the control of injurious insects is well known and has been greatly exploited by the Americans during the last forty years, notably in the introduction of the Australian ladybird, *Novius cardinalis*, to destroy the fluted scale of the orange in California. This method is followed to a somewhat limited extent in America with other introduced pests, and has been adopted in Italy with success in certain instances.

However, Americans were not the first to use such means for guarding against diseases. In reading, we find that our ancestors always used natural enemies as a precaution against different contagious diseases.

Livy points out that in the year 293 B.C. the Romans were afflicted by a plague. By advice of the Sibylline Books they sent an embassy to Epidaurus to seek advice from the priests of Asclepius and to ask for a remedy for the disease. Upon its return the embassy brought to Rome a serpent, which the Romans received and worshiped as a god. The serpent swam from the boat to the island of Tiberius opposite the Capitol—the so-called sacred island where the Romans built a temple to this new god, and for many years thereafter people painted pictures of serpents upon their walls. What was the effect of the serpent in this instance of plague? Was it simply a question of the god who had brought about the end of the epidemic? Professor Sambon, pointing to this example to-day, believes that there are serpents which feed upon mice, the carriers of disease, and that through the destruction of the mice the epidemic also is destroyed. A coin in Pergamum of Lucius Severus (161–169) supports this hypothesis. The coin was struck after a plague; it shows Asclepius holding a serpent in his right hand and a rat in his left. We find other analogies among the Egyptians, who worshiped the scarab because it destroyed worms, and the ibis which fed upon different snails in the Nile. They used to guard themselves from serious diseases, as the hookworm disease and the two Schistosomias.

THE PROCESSION OF FOREIGN INSECT PESTS

By Professor GLENN W. HERRICK

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THE advent of the Mediterranean fruit-fly (*Ceratitis capitata*) into Florida has brought home to the average man in a most forcible manner the serious menace inherent in the possible introduction of a foreign insect. Perhaps no insect pest ever imported into the United States, with the possible exception of the European corn-borer (*Pyrausta nubilalis*), has exerted a more immediate effect on the economic conditions of so large a body of citizens. It is only fair to the fly, however, to say that this effect has not been produced by its own activities or through its own destructiveness, but it has come rather as a result of measures of extermination and quarantine instituted by man himself. It is worth while at this time to reflect upon the foreign insect population of this country—its procession in time, the behavior of certain of its members and its relation to quarantine measures.

From the days of the early colonists foreign insects have been coming into this country in a continuous, persistent procession apparently in spite of any measures taken to prevent them. The following list of the more common older pests and of some of the more recent ones that have come to us from foreign countries will show the continuity of the procession in point of time:

Codling-moth (*Carpocapsa pomonella*), introduced prior to 1750.

Hessian fly (*Phytophaga destructor*), introduced about 1779.

Pear psylla (*Psylla pyricola*), introduced about 1832.

Imported elm-leaf beetle (*Galerucella luteola*), introduced about 1834.

Currant sawfly (*Pteronidea ribesi*), discovered in 1857.

Imported cabbage worm (*Pontia rapae*), introduced about 1860.

Gypsi moth (*Porthetria dispar*), introduced about 1869.

San Jose scale (*Aspidiotus perniciosus*), discovered in 1879.

Larch case-borer (*Coleophora laricella*), discovered in 1886.

Mottled willow borer (*Cryptorhynchus lapathi*), discovered in 1887.

Brown-tail moth (*Euproctis chrysorrhœa*), introduced between 1890 and 1893.

Mexican cotton-boll weevil (*Anthonomus grandis*), introduced in 1892.

Carrot rust fly (*Psila rosae*), discovered in 1901.

Alfalfa weevil (*Phytonomus posticus*), discovered in 1904.

European earwig (*Forficula auricularia*), 1909.

European pine-shoot moth (*Evetria buoliana*), introduced about 1914.

Pine sawfly (*Diprion simile*), discovered in 1914.

Japanese beetle (*Popillia japonica*), discovered in 1916.

Oriental peach moth (*Laspeyresia orientalis*), discovered in 1916.

European corn-borer (*Pyrausta nubilalis*), discovered in 1916.

Tropical fowl mite (*Liponyssus bursa*), discovered in 1916.

Banana-root borer (*Cosmopolitas sordidus*), discovered in 1917.

Pink cotton boll-worm (*Pectinophora gossypiella*), discovered in 1917.

Apple and thorn skeletonizer (*Hemerophila pariana*), discovered in 1917.

Asiatic beetle (*Anomala orientalis*), discovered in 1920.

Satin moth (*Stilpnotia salicis*), discovered in 1920.

Camphor scale (*Pseudaonidia duplex*), discovered in 1920.

Mexican bean beetle (*Epilachna corrupta*), discovered in the east in 1920.

New oriental beetle (*Pseudocneorrhinus setosus*), discovered in 1920.

Australian tomato weevil (*Listroderus obliquus*), discovered in 1922.

Oriental twilight beetle (*Aserica castanea*), discovered in 1921.

Cabbage weevil (*Ceutorhynchus erysimi*), discovered in 1923.

Grape thrips (*Drepanothrips reuteri*), discovered in 1927.

Mexican fruit-fly (*Anastrapha ludens*), discovered in 1927.

Mediterranean fruit-fly (*Ceratitis capitata*), discovered on April 6, 1929.

In pondering this list with its dates of introduction one can scarcely refrain from asking what the stiff quarantine regulations against the vegetable, fruit, cereal and other products of foreign countries instituted some fifteen or more years ago have accomplished in preventing the introduction of undesirable insect visitors. No one can say. Perhaps dozens of unknown dangerous species have been kept out. Two things, however, are certain: namely, that some of the more recent ones which "got by" are now among our most serious pests, and that it is, apparently, very easy for these small animals to enter our country.

On my return from Europe in the autumn of 1926 on the good ship *Orca* I was greatly interested to find on the dining table at breakfast one morning a fine lively female individual of the clover-leaf weevil, a European clover pest which, although it had come to us many years ago, was apparently entering the country again. Whether this tiny weevil had climbed aboard at Cherbourg, France, or at Southampton, England, I had no means of knowing, but there she was, lively and happy, ready, no doubt, to disembark at the pier in New York without any worry concerning quarantine at Ellis Island or the fierce ways of the customs officers in New York and without saying "by your leave" to anybody. She hadn't counted, however, on meeting an entomologist who upset all her plans at once, for now her mortal remains repose on a small black pin in a special case in the writer's collection.

The Migratory Behavior of Some Introduced Insects

It is of considerable interest to examine briefly the behavior of a few of these foreign insects after they become established in this country. The spread of the Mexican cotton-boll weevil is well known and in some respects is significant. A glance at the diagram will show that the weevil spread eastward over the cotton belt, from its center of infestation in Texas, with an irresistible yearly progress despite any state or local quarantine measures instituted against it. The significant aspect of this migration is that the weevil did not jump ahead and form isolated outbreaks here and there, but spread outward in uniform waves passing over all human obstacles.

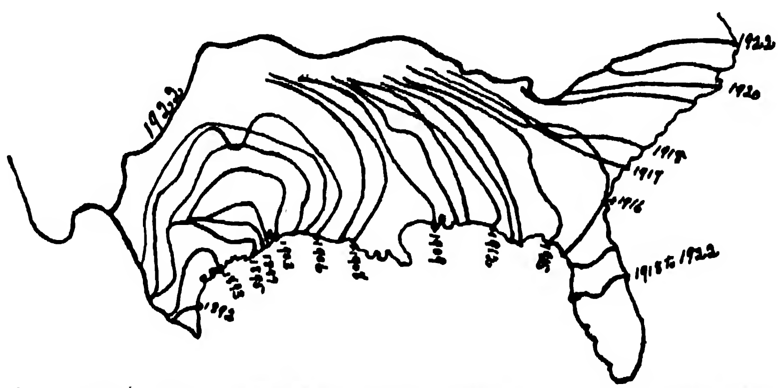


Fig. 1. A diagram, showing the steady eastward migration of the cotton-boll weevil. Adapted from Hunter and Coad.

The map showing the spread of the Mexican bean beetle in the east after its jump into the middle of Alabama exhibits a similar, steady, irresistible wave-like migration from year to year without sporadic outbreaks in advance (Fig. 2).

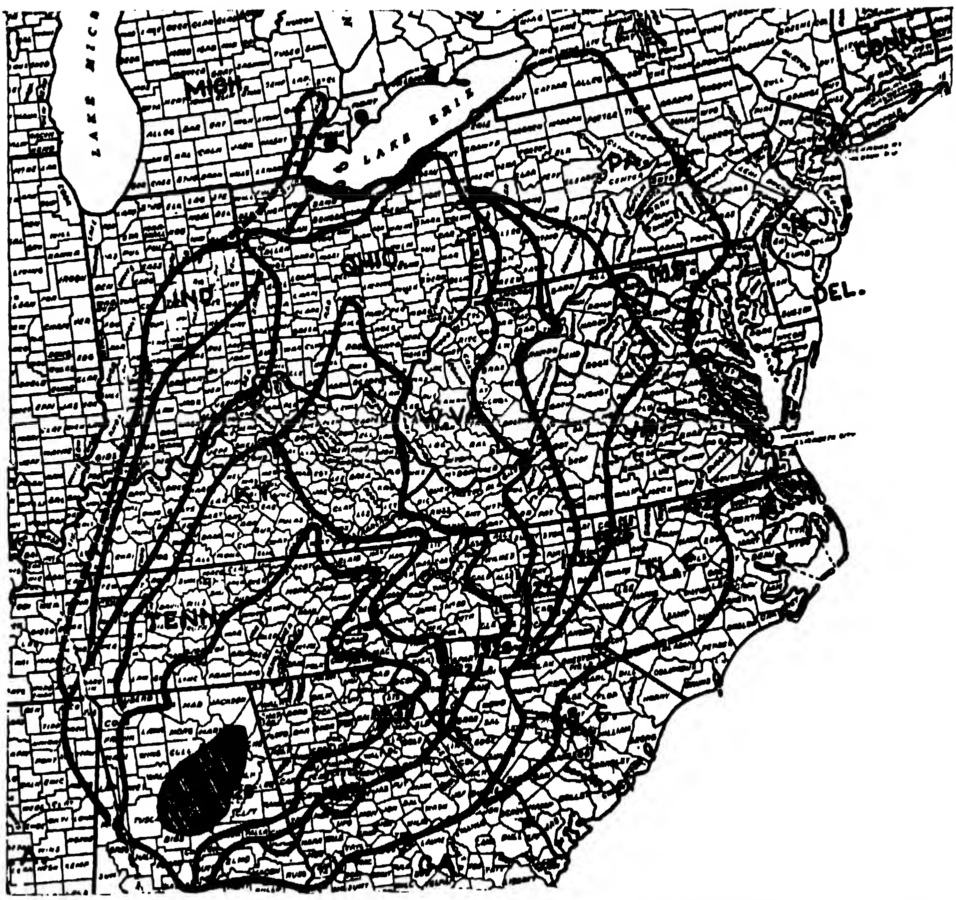


FIG. 2. MAP INDICATING THE YEARLY SPREAD OF THE MEXICAN BEAN BEETLE FROM ITS CENTER IN ALABAMA. AFTER N. HOWARD.

The gradual migration of the European corn-borer from its centers of infestation in New York and Canada presents a similar behavior—with no sporadic outbreaks ahead of the general wave-like spread of the moth (Fig. 3).

The Japanese beetle (*Popillia japonica*) is behaving in a similar manner, spreading outward from its original area in eastern Pennsylvania at about an annual average rate of from fifteen to twenty miles. It will probably travel somewhat faster as it gathers momentum during the coming years.

A careful, thoughtful consideration of the migratory habits of such active winged forms as the foregoing species certainly moves one to question the justification for the rigid quarantine measures placed over the areas infested by such insects. These measures are always annoying, always sources of friction and in many cases cause serious losses, if not ruin to individual growers. Besides, the maintenance of the quarantines entails a heavy expense which, of course, falls as taxes upon the people whom they injure as well as upon those whom they are supposed to benefit. The problems connected with the introduction and dispersion in this country of these imported pests should certainly be studied from

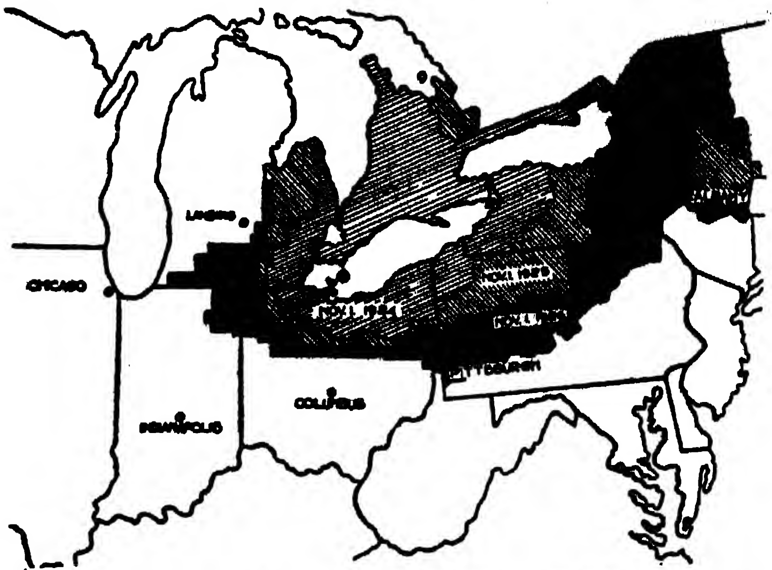


Fig. 3. Map showing the distribution of the European corn-borer as known November 1, 1926. The outside (darkly shaded area) indicates the spread of the pest which is believed to have occurred during the summer of 1926. (Infested area in New England not shown.) After Caffrey and Worthaler.

all angles and attacked in a broad, constructive manner helpful to all the interests involved as far as possible.

There is, however, another class of insects which demands further consideration. I refer to those which are fixed to some host plant during the greater part of their lives and are practically restricted in their migratory movements to the wanderings of their hosts. The scale insects are the most important members of this group and perhaps the San Jose scale is the most notable example. The San Jose scale has undoubtedly been carried around the world on its host plants in commercial shipments of nursery stock. It jumped from California to Missouri and thence to the eastern seaboard, probably on plum stock shipped from one nursery to another. From these early centers of infestation the insect has been carried all over this country on infested nursery stock. Reasonable quarantine and inspection measures instituted for nursery stock seem to me to be wise, sane and justifiable, and every honest successful nurseryman recognizes the advantages to his business of growing and distributing clean stock.

California has probably been the most active state in the union in maintaining rigid quarantine measures against the introduction of foreign insect pests. Moreover, she has probably obtained the greatest success in excluding these unwelcome guests not because her officials have been wiser, more active or more efficient than the officials of other states but rather because of her advantageous situation. California constitutes a comparatively narrow strip of land extending north and south and bordered on the west by a great water barrier and on the east by an almost impassable land barrier of desert and high mountains. Such a situation constitutes an ideal area for protection against foreign insect foes because it is feasible to guard rather effectively the few points of entry into the state, namely, the few seaports along the Pacific coast and the few passes through

the desert and mountains on the east. Even with these advantages California has not altogether escaped her foreign foes and can not hope to remain untouched in the future, although her invasions will come more slowly but scarcely the less surely.

The Mediterranean fruit-fly has emphasized the whole problem of the invasion of our country by foreign pests and has raised many puzzling questions concerning methods of dealing with so serious a guest. Any statements the writer may make regarding this insect are made with great hesitation, because we do not have extensive knowledge of the habits and activities of the fly and can only guess at its future behavior in this country. Some phases, however, of its activities as a pest of fruits in Europe and in the Hawaiian Islands have been described in some detail by dependable observers.

In the Mediterranean countries in which the fly is present the principal citrus fruits are being produced apparently in paying quantities. In South Africa the fly is not considered a serious pest of citrus fruits. It is, however, very injurious to deciduous fruits, particularly peaches and apricots, but can apparently be controlled on these fruits by using a poison bait if the wild host fruits in the vicinity are destroyed. In Hawaii the fly is a serious pest, particularly in villages, but the conditions in those islands are peculiarly and most favorably suited to the development and multiplication of the insect. Comparable conditions are scarcely to be found anywhere in this country.

Again, the lemon is practically immune to the attacks of the fly. The orange is more subject to the egg-laying of the fly but does not appear to be seriously infested by the maggots in the pulp if the fruits are not allowed to remain on the tree until they become overripe. Investigators speak of the "wonderful resistant power of the oranges to fruit-fly attack." The sour orange appears more susceptible than the sweet ones. Grapefruit are also "particularly resistant to attack up to the time when they are fit for table use." These statements regarding lemons, oranges and grapefruit are founded on studies of the fly made by careful investigators in Hawaii where the conditions are particularly favorable for the insect.

On the other hand, the fly, under some conditions at least, is a most serious pest of other fruits, especially of peaches, plums, pears and apples when these fruits are grown in warm or subtropical climates. Apropos of this phase of the activities of the fly the following quotation from well-known entomologists who have been in intimate contact with the fly is of great interest.

> At 50° F. little if any development takes place, and freezing temperatures can be withstood successfully only for short periods. Accumulated data indicate that the Mediterranean fruit-fly will not become a serious pest in climates where the mean temperature is below 50° F., during periods covering three months of the year.

In the light of this statement it is important to examine the mean temperatures of Georgia, the first great peach-growing territory north of Florida. A cursory examination of the temperatures for the middle section of Georgia including the peach-growing area about Fort Valley shows that the normal mean temperature for December is about 45° F., for January about 44° F. and for February about 45° F. Moreover, the minimum temperatures for this region during December, 1908, for example, varied from 24° to 31° F., during January from 11° to 25° F., while during February they varied from 15° to 23° F. Thus over most of the middle section of Georgia the normal mean temperature is well below 50° F. and there seem to be freezing temperatures at vary-

ing intervals during at least three months of the year. Judging from the meager data at hand it would appear that the fly would be killed during the winter in the middle and northern parts of Georgia and in order to infest the peach crop of any particular year would have to re-enter the state from centers of infestation farther south. It is pertinent to inquire whether the fly when subject to extermination once a year in a given region could ever become a pest of prime importance in that region.

One more quotation from the investigators who were quoted above is worthy of consideration. The studies of these men in the Hawaiian Islands lead them to make the following comment:

> While Hawaiian conditions are unfavorable to the use of poison sprays, the work of the writers has convinced them that these sprays can be employed as successfully in combating this pest in commercial orchards of California and of the southern states, should they ever become infested, as in Africa and Australia.

This is a most hopeful statement and from my experience in combating the cherry and apple fruit-flies, close relatives of the Mediterranean fly, I believe it is a sane and reasonable one.

THE DISCOVERY OF A NEW ANTHROPOID APE IN SOUTH AMERICA?

By Dr. FRANCIS M. ASHLEY-MONTAGU

THE ROYAL ANTHROPOLOGICAL INSTITUTE OF GREAT BRITAIN AND IRELAND

THE discovery of new monkeys or apes, apart from their importance, is always of the greatest interest. Not alone do such discoveries provide systematists, anthropologists and other scientists concerned with the study of the Primates—the order of mammals to which man belongs—with much pleasurable labor, but that great public which is interested in the past and future evolution of man, and which attentively follows the newest developments in the fields of spiritual and physical humanism, is ever stirred to the most wholesome enthusiasm on such occasions.

On the eleventh of March, 1929, Dr. George Montandon, of the Muséum National d'Histoire Naturelle, Paris (a well-known anthropologist, and the author of an ingenious theory, the Ologenic theory of anthropogenesis, which holds that the anthropoids and man originated independently over the whole of the earth), announced to the scientific world the discovery of a new and hitherto unknown anthropoid ape.[1] This announcement in itself was sufficient to engender the liveliest interest among scientists. When, however, it was learned that this ape was discovered in South America, a continent in which anthropoids were hitherto completely unknown and in which it was considered extremely unlikely that they should exist, the find took on the dimensions of an epoch-making discovery.

Dr. Francis de Loys, the discoverer of this Primate, and Dr. George Montandon, who was entrusted with the task of presenting the facts to the scientific world, have been kind enough to send me the material upon which this paper is based, and I wish here to express my cordial thanks to them. The facts are as follows.

Dr. de Loys, a geologist, was exploring in the neighborhood of the Tarra River, an affluent of the Rio Catatumbo, in the Motilones districts of Venezuela and Colombia, at a bend of a western minor affluent of the Tarra River, when two huge monkeys, one male, the other female, suddenly broke out upon the exploring party, which was then at rest. Owing to the violence of their attitude, the animals had to be received at the point of the rifle. One of the two was instantly shot dead at very close range, the other, which was unfortunately wounded, managed to get away in the thick growth of the jungle and make good its escape.

The dead animal, which was found to be an adult female, was immediately set up on a box and photographed, certain measurements were then taken, the animal was skinned and its bones cleaned. The subsequent hardships encountered by the party on their long and hazardous journey across the forest unfortunately prevented the final preservation of either the skin or the bones.

When measured, the height of the animal was found to be 157 cms (approximately five feet two inches), and its weight was roughly estimated to be somewhat over eight stone (say 115 pounds). The body, which was entirely covered with a thick coat of coarse, long, grayish-brown hair, was, according to Dr. de Loys, entirely devoid of any trace of a tail. "The jaw, carefully

[1] *Comptes Rendus* des Séances de L'Académie des Sciences, March 11, 1929.

FIG. 1. THE ANIMAL IMMEDIATELY AFTER IT HAD BEEN SHOT

examined, revealed the presence of thirty-two teeth only, without on the back portion of the mandible, any protuberances hinting at the possibility of a greater number of embryonic molar teeth."[2]

All these features, "size, absence of tail, number of teeth and ground habits, together with the strongly humanoid aspect of the face and the ruggedness of the build," lead Dr. de Loys to believe that this creature is a hitherto unknown anthropoid ape.

The two photographs which I am here able to reproduce by the courtesy of Dr. de Loys should convey a good idea of the creature. The object depending from the puberal region between the legs, and which looks like a male copulatory organ, is, in fact, the enormously enlarged clitoris, which, possibly owing to a local hyperemia, corresponding in the male to a condition known as priapism, has been forced out of the vagina. Whatever its cause may be, it is none the less an extraordinary phenomenon.

Careful inspection of these photographs reveals the following facts:

(1) The human-like rounded head presents (*a*) a prominent forehead, and (*b*) there are no markedly overhanging brow-ridges; the nose is wide and presents a broad septum between the outwardly deflected nostrils—characters which are peculiar to the New World monkeys generally, and specifically to the genus *Ateles*.

It is a curious fact that none of the Old World monkeys and apes possesses a forehead as prominent as that found in many New World monkeys. The high forehead, which is so distinctively human a characteristic, is primarily what lends so human an appearance to the head of this creature, whose face is identical in

[2] *The Illustrated London News*, June 15, 1929.

appearance with most species of the genus *Ateles*. In no Old World monkey and in no ape, however, are the nostrils separated by a wide septum, nor are the nostrils so flaring and deflected in an outward and upward direction—this condition is peculiarly South American, there being only three New World genera in which there is an approximation to the Old World arrangement of a narrow septum and inwardly directed nostrils, namely, *Alouatta*, *Aotus* and *Brachyteles*.

(2) With the aid of a magnifying glass one may perceive that the thumb is a much reduced, nail-less tubercle, the merest excrescence upon the side of the hand. This is a characteristic which is specifically associated with *Ateles*, for no other South American monkey possesses so reduced a thumb. None of the Old World monkeys and apes possesses such a character; in only the Orang-Utan, in which the thumb is the most reduced but is quite large compared with this creature's, is the thumb occasionally lacking in a nail. It is clear enough from the photograph that this creature's hands are adapted to an extreme arboreal existence.

(3) The feet are evidently of the quadrupedal grasping type, normally associated with an arboreal life. Doubtless, this creature could support itself on its hind legs, but the structure of its foot renders it quite impossible that its habitual gait is bipedal rather than quadrupedal, or that it spends more time upon the ground than in the trees. This foot is identical in appearance with that of *Ateles*.

(4) The fact that the body was entirely devoid of any trace of a tail (an appendage which is possessed by all South American monkeys) would certainly convince us that we are here dealing with a new species of monkey, but, unfortunately, we can not quite eliminate the possibility of this particular creature having lost its tail in early infancy, thus accounting for there not being even the "trace of a tail." Monkeys have often been known to bite off the tail of some other monkey, the males not infrequently injuring their young in this way. There are, however, a number of other ways in which it is possible to explain the loss of the caudal element in any monkey, but with them we need not concern ourselves here.

(5) Dr. de Loys is quite convinced that the jaw held only thirty-two teeth—a number associated with the Old World Primates and man only. Dr. de Loys does not, however, give the formula for these teeth. In the New World monkeys the formula is $\frac{\text{M3, PM3, C1, I2}}{\text{M3, PM3, C1, I2}}$, that is, three molars, three premolars, one canine and two incisors, for each half of the jaw, in all, thirty-six teeth. The Old World monkeys have lost one premolar in each half of the jaw, thus they possess thirty-two teeth only. If the creature we are here dealing with has lost a premolar, is it not curious that Dr. de Loys should have looked for it on the back portion of the mandible, where only the true molars grow? The bare statement that the jaw held only thirty-two teeth conveys very little to us, for such a statement may mean either that there were only two premolars, or that there were three premolars and two molars (the third having failed to erupt, or to develop), and how are we to decide which is true? The latter condition is the most unlikely one, so that we must provisionally accept the former as the true one.

(6) As far as the stature is concerned, I am not aware of any South American monkey which reaches a height of more than 90 cms (three feet), although this height may conceivably be exceeded in some cases. Certain it is that the height of five feet two inches and the weight of 115 pounds of this monkey are quite un-

FIG. 2. ENLARGEMENT OF THE HEAD

known in any South American monkey. Nor would it appear from an examination of the photographs that these features are due to any anomalous or pathological causes, although such a possibility can not be altogether eliminated. Assuming, however, that there does exist a species of monkey of which that figured here is a normal representative in the matter of height and weight, it becomes certain that we are here dealing with at least a new subspecies of monkey.

The only characters, then, which distinguish this creature from all other South American monkeys are (1) the absence of a tail, (2) the presence of only thirty-two teeth, (3) its height and weight. The number of teeth alone is a character sufficient to justify the creation of a new genus to receive this animal; the absence of a tail, and the height and weight present ancillary reasons for such a procedure but these features are quite insufficient to justify the appellation of *Anthropoid* which has been ap-

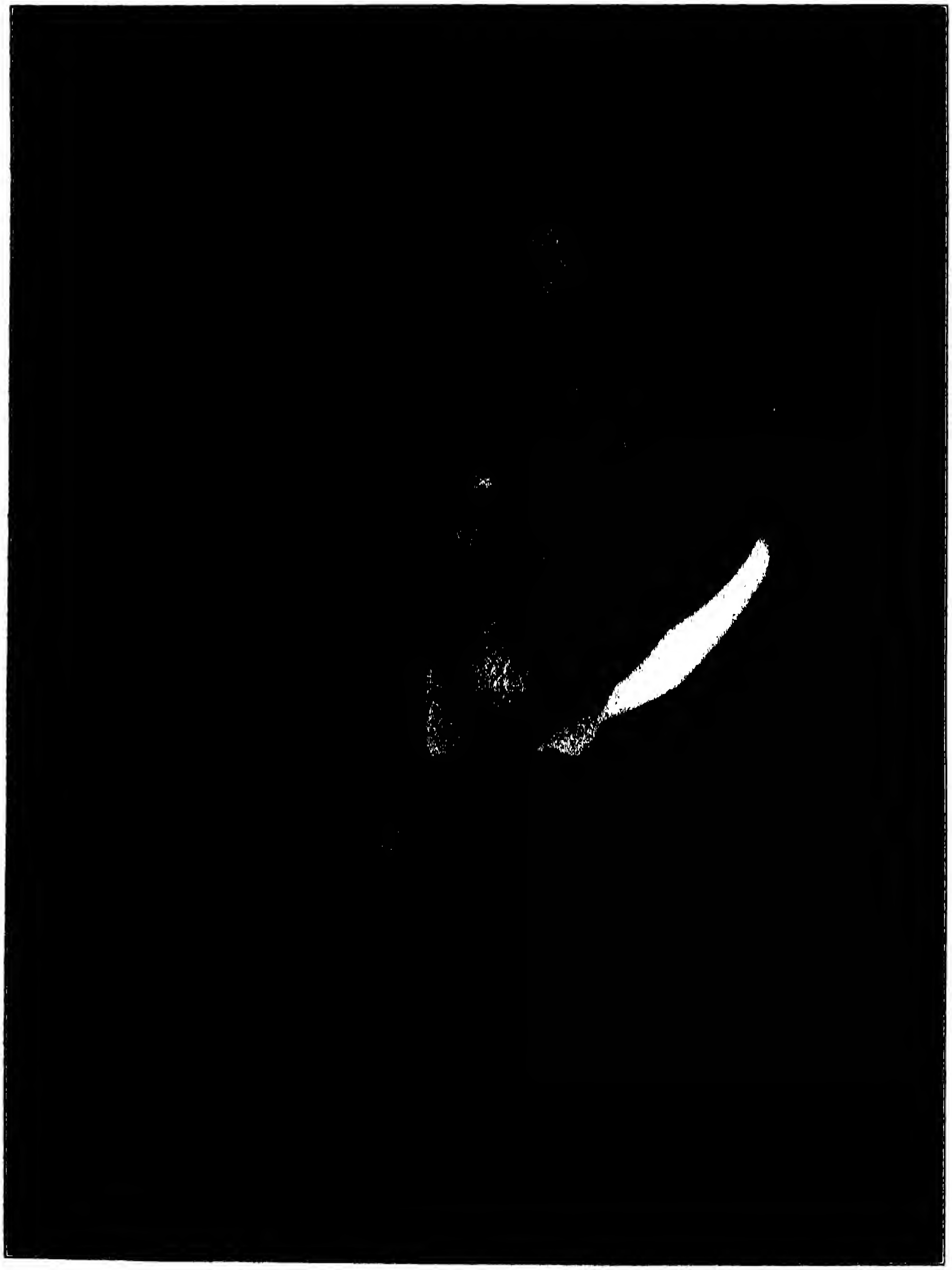
plied to it by Dr. Montandon. Dr. Montandon creates a new genus (as he calls it, but which is really a new subfamily), *Amer-anthropoidés*, comprising the single species (*Loysi*), whilst reserving the possibility, however, of this being a new species of the genus *Ateles*.

Now exceptional weight and height can at best be regarded as subspecific characters. The absence of a tail in any New World monkey would endow it with specific, but not with generic rank, whilst the loss of a premolar would serve to separate it from all other New World Primates. Neither taillessness nor the loss of a premolar would, however, distinguish this creature, in these respects, from those monkeys of the eastern hemisphere which lack tails. Since, as far as we know, no Old World monkey attains a height of 175 cms nor a weight of 115 pounds, it seems that Dr. Montandon has seen in this (on the basis of its taillessness and its dentition), an adequate reason for endowing this creature with the rank of an anthropoid. That is to say, he has converted a subspecific into a generic character having a sub-family rank, a procedure which is quite unjustified by the facts, and contrary to any natural system of classification.

The most, I think, we can say of this creature is that it is a new genus of monkey, possibly an aberrant type, but at any rate, a close relative to *Ateles*.

It is to be deeply regretted that Dr. de Loys was unable to make a number of photographic records of the skull and other bones; doubtless he little thought of the contingency of losing the actual bones. If a photograph had been made in this case of the skull and the teeth alone, we would have been saved a considerable amount of trouble in speculating about the possibility of this being a new genus of monkey or not; as it is, we have only the observation of Dr. de Loys to rely upon, which, even if he were the most accomplished observer in the world, is not sufficient to satisfy scientific standards of accuracy.

It has ever been the custom to deride the new discovery of apes—the classic case of Du Chaillu and the gorilla is yet fresh within living memory (1859–65), whilst the story of the acrimonious battles which have raged over the discovery of the remains of extinct races of man is too well known to require any amplification here. Let us here bear these events in mind, and endeavor not to commit a like injustice; let us also, however, be cautious, lest in our anxiety to be just we grant too much, and say, until further *real* evidence is forthcoming, the only attitude to adopt in this matter is that of suspended judgment.



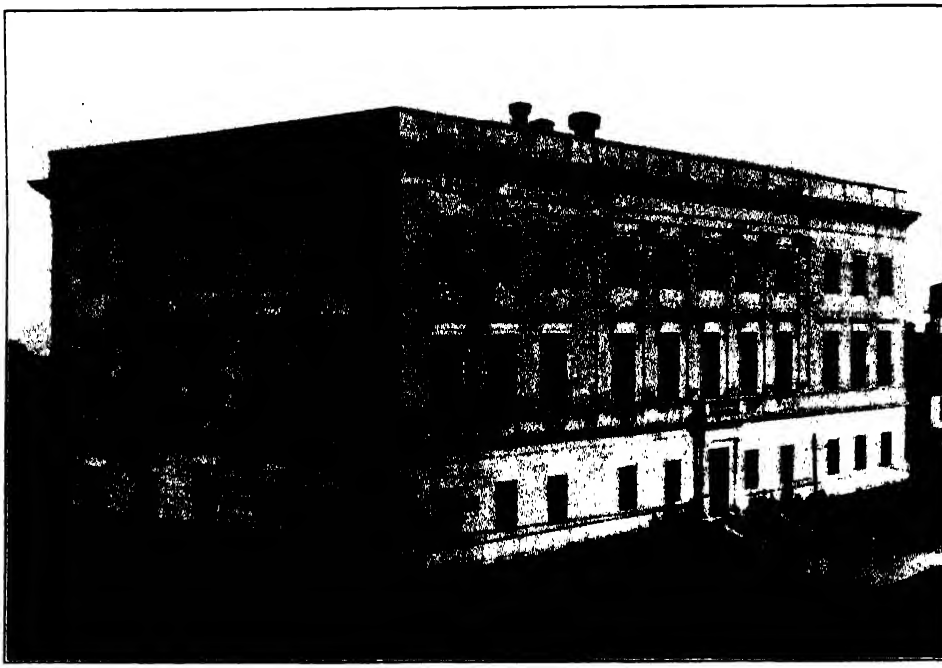
DR. WILLIAM H. WELCH

THE PROGRESS OF SCIENCE

THE WILLIAM H. WELCH MEDICAL LIBRARY AND THE DEPARTMENT OF THE HISTORY OF MEDICINE OF THE JOHNS HOPKINS UNIVERSITY

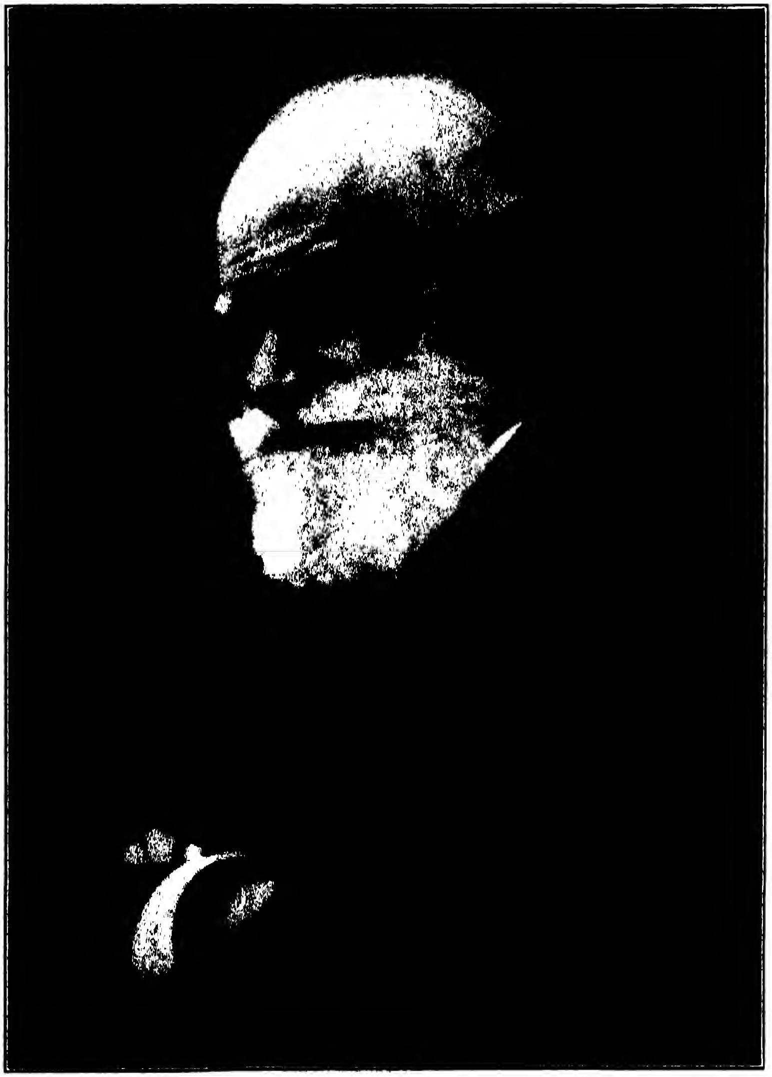
On Thursday and Friday, October 17 and 18, the William H. Welch Medical Library and the new Department of the History of Medicine of the Johns Hopkins University will be opened with appropriate exercises. Both the Welch Medical Library and the Department of the History of Medicine have been under consideration by the Johns Hopkins University for some years and their establishment may be said to mark the fulfillment of plans made with the opening of the Johns Hopkins Hospital and School of Medicine. At that time a historical club was organized, chiefly through the activity and interest of Dr. Welch and Dr. Osler, ably seconded by Dr. Kelly and Dr. Halstead. From time to time lectures on the history of medicine were given in the medical school but the historical club continued for many years as the chief center of interest for those to whom the historical aspect of medicine especially appealed. The final establishment of the Department of the History of Medicine, however, is closely bound up with the career of Dr. Welch. Called from Bellevue Hospital Medical College in 1884 to become Baxley professor of pathology in the Johns Hopkins University, after a distinguished career in New York City, Dr. Welch organized a modern institute of pathology in Baltimore in which numerous talented young men and women have been trained in pathological anatomy and in bacteriology, especially in the bacteriology of the infectious diseases. In 1916 Dr. Welch retired from the chair of pathology, his successor being one of his own pupils, Dr. W. G. MacCallum, professor of pathology in Columbia University, New York, and undertook the organization of the new school of hygiene and public health, made possible to the Johns Hopkins University by the generosity of the General Education Board. At the same time Dr. Welch was busily engaged in the United States Army, as a member of its medical corps. In 1926 Dr. Welch resigned from the directorship of the school of hygiene and public health to become professor of the history of medicine in the medical school, his place as director being filled by the present incumbent, Dr. W. H. Howell. This professorship in the history of medicine is the first full-time professorship in this subject in America, and there are but two or three completely endowed institutes of medical history in Europe. The Johns Hopkins University is indeed fortunate in securing Dr. Welch for this post, since he combines in an unusual degree a complete training in the medical sciences with a profound knowledge of their history.

About the time that the professorship in the history of medicine was established, the necessary funds were secured from the General Education Board and from unnamed and generous donors for the construction and endowment of a medical library to house the collections of books and journals in the libraries of the Johns Hopkins Hospital, School of Medicine and School of Hygiene and Public Health. Very appropriately this medical library has been named after Dr. Welch who has been so long identified with the three institutions which it will serve. Mr. E. L. Tilton, of New York, an authority on the architecture of libraries, was asked to plan the library building which was completed in November, 1928, the three constituent libraries



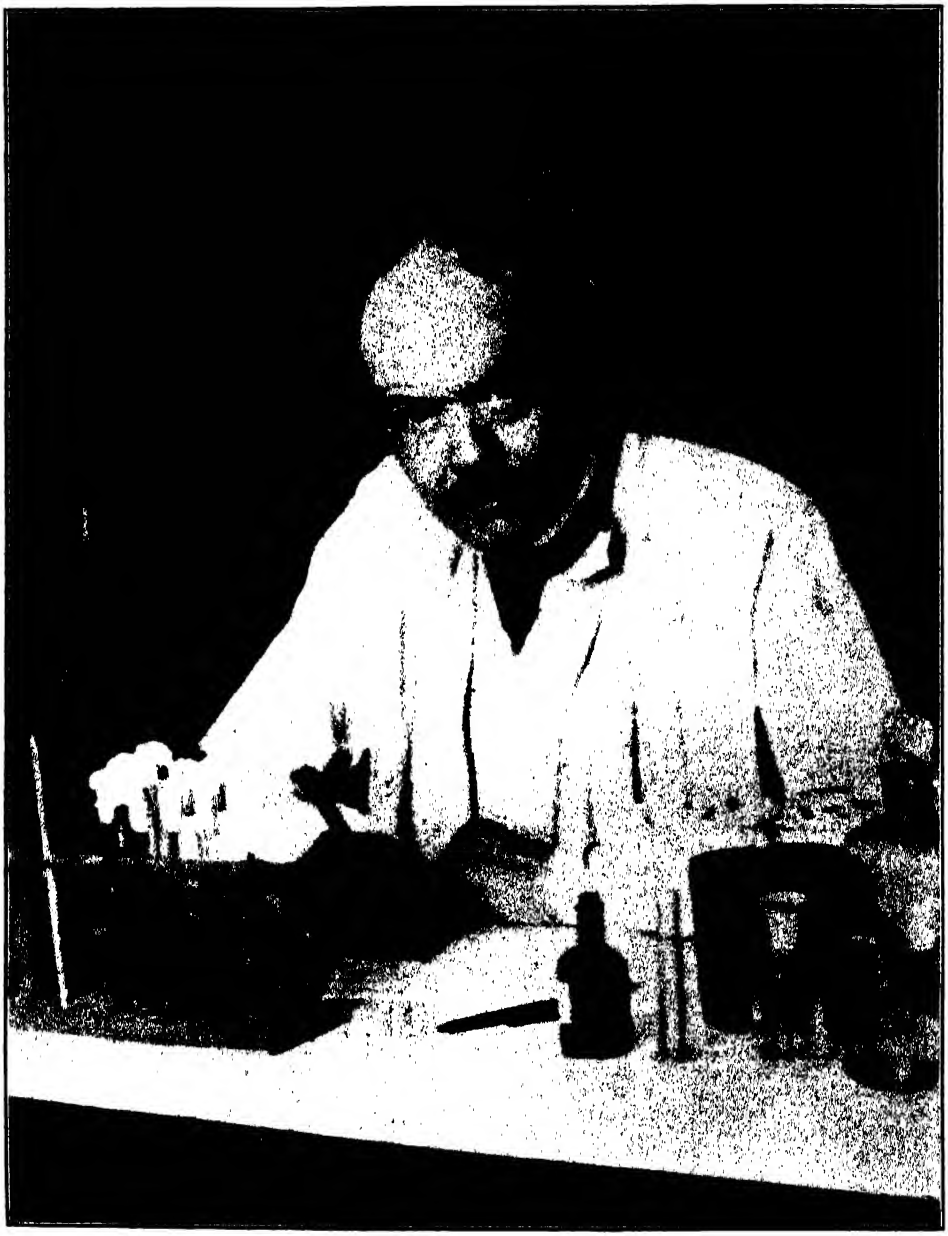
THE WILLIAM H. WELCH MEDICAL LIBRARY

being transferred to it within a short time. The Welch Library building merits somewhat more extended notice than is here possible. In brief, it consists of three floors of which the ground floor is devoted to the offices of the library personnel and to rooms for cataloguing and binding books. On the second floor is a large corridor in the center with a reading room at one end and a reception hall, the Great Hall as it will be called, at the other. The reading room is large enough to accommodate about a hundred readers and connects directly with the stacks. The Great Hall is especially designed for receptions and conferences. The decorations of this room have been executed by Mr. Lascari, of New York, and in it has been placed Sargent's portrait of the four doctors, Dr. Welch, Dr. Osler, Dr. Halstead and Dr. Kelly, which has hitherto been hung in Gilman Hall at Homewood. On the third floor are about a dozen rooms for the Department of the History of Medicine, offices, lecture rooms, conference rooms and a number of small studies for members of the staff. The back part of the building contains the stacks for books, eight tiers in height, with a large number of small cubicles for individual workers. The stacks are large enough to hold several hundred thousand volumes and are of course at present only partially occupied. The hospital library, which was begun with the opening of the hospital, contained about 25,000 books and journals, dealing chiefly with the clinical branches of medicine, the library of the school of medicine, about 15,000 volumes, dealing principally with the underlying medical sciences and the library of the school of hygiene about 10,000 books concerning hygiene and public health. In addition to these 50,000 volumes are a considerable number of special collections which have been presented to the library by its



PROFESSOR IVAN PAVLOV

OF THE UNIVERSITY OF LENINGRAD, WHO WILL CELEBRATE HIS EIGHTIETH BIRTHDAY ON SEPTEMBER 22 IN THE UNITED STATES, WHERE HE HAS COME TO ATTEND THE INTERNATIONAL CONGRESSES OF PHYSIOLOGY AND PSYCHOLOGY.



DR. CH. NICOLLE

DIRECTOR OF THE PASTEUR INSTITUTE AT TUNIS, TO WHOM A NOBEL PRIZE IN MEDICINE HAS BEEN AWARDED IN CONSIDERATION OF HIS WORK ON TYPHUS, MORE ESPECIALLY ON THE PART PLAYED BY LICE IN CARRYING THE DISEASE.

friends and which will gradually be amalgamated with it. Among these contributors may be mentioned especially Dr. Kelly and Dr. Young who have donated a number of rare and valuable books dealing with medical history. The libraries of the late Dr. Halstead and the late Dr. Hurd have also been bequeathed to the university and will be cared for in the Welch Library. Finally, Dr. Welch spent a long period of time abroad, while the library building was under construction, gathering books in medical history from various sources in Europe, especially in London, Paris and Amsterdam. The library starts, therefore, with well over 75,000 volumes and it is anticipated that several thousand accessions will be made each year.

On Thursday the Welch Medical Library will be formally dedicated at 11 o'clock at which time it is expected that Dr. Harvey Cushing, of Harvard University, will make the principal address. The afternoon will be given up to a conference on medical libraries and in the evening there will be a large public reception for the inspection of the library building. On Friday the Department of the History of Medicine will be inaugurated. Dr. Welch will preside and outline his plans for the organization and development of the department. The address on this occasion will be given by Professor Karl Sudhoff, of the University of Leipzig. The afternoon will be devoted to a conference on the history of medicine and to an exhibition of the Harvey Tercentenary Film. Friday evening will be reserved for private entertainments and dinners. It is hoped that many of the graduates of the university, former house officers of the hospital and the numerous friends of Dr. Welch will make the dedication of the library named in his honor and the inauguration of this new department in the university which he will head, the occasion of a visit to Baltimore.

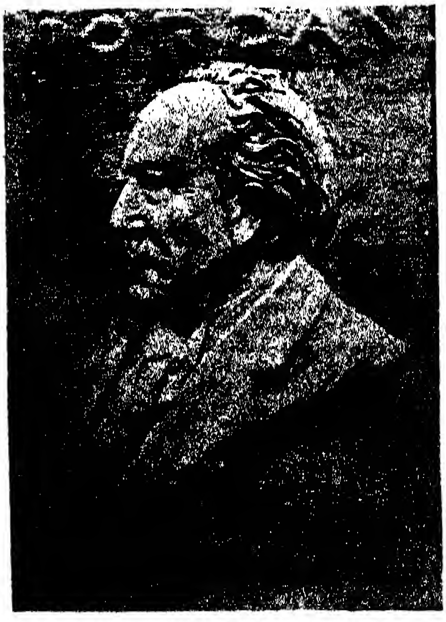
THE PHYSIOLOGICAL EFFECTS OF SUPER-SONIC WAVES

A "DEATH WHISPER," which causes matter within living cells to whirl to destruction without injuring the cell walls, has been produced in experiments conducted jointly by Dr. E. Newton Harvey, professor of physiology at Princeton University, and Alfred E. Loomis, of the Loomis Laboratory, of Tuxedo Park, N. Y. This dance of death within the cell is caused by supersonic waves which oscillate twenty times as rapidly as those which can be heard by the human ear.

Chloroplasts within the cells of living plants are forced from their usual positions by these super-sonic waves and are driven at high speed in miniature whirlpools about the center of the cell.

Under a high-power microscope it is possible to follow the progressive destruction of blood corpuscles of a frog. The oval cells at first become warped and twisted. Strained areas appear and the color fades, leaving a pale distorted shadow. Human corpuscles are likewise twisted and sometimes broken up into many small globules, like an emulsion of oil.

The super-sonic waves are produced by a miniature radio broadcasting apparatus which causes a quartz crystal to vibrate. The apparatus is operated on 110 volt alternating current and employs a 75-watt tube with two small transformers. The apparatus has been so devised that the quartz crystal, the producer of the super-sonic waves, can be placed on the stage of a microscope with the specimen to be studied above it in the direct path of the waves. In



TRIBUTES TO DR. DAVID STARR JORDAN

In the photograph by Burt Davis, Dr. Jordan, chancellor emeritus of Stanford University, is shown in his garden in Palo Alto with a gift sent him by Stanford graduates in Tokyo to mark his efforts for world unity and peace. It is mainly of bronze with gold and silver overlays, and consists of the figure of a dove perched on a broken temple roof. Below is a plaque of Dr. Jordan by Carleton B. Angell, which will be hung in the hall of the new museum building of the University of Michigan. We owe the illustrations to the courtesy of *The Stanford Illustrated Review.*

this way it has been possible for the first time to examine the effect of the "death whisper" upon microscopic cells. By governing the intensity of the waves, the whirling or mixing of the matter within the cells can be accurately controlled.

Professor Harvey, who has been working for a number of years as well upon the production of "cold light," refused to predict what effect the study of the properties of super-sonic waves might have upon the medical science of the future. At present experiments are being conducted to find out what effect the mixing of organ-forming substances within the eggs of marine life will have upon the young which develop from them.

The microscopic method is said by Dr. Harvey to offer a promising means of attack upon the problem of influencing the development of eggs of various species, as forces can thus be applied inside an egg at different stages of its development without the necessity of puncturing the cell wall or enveloping membrane. The results suggest the interesting possibility of converting an egg with determinate cleavage into an indeterminate one by thoroughly mixing and redistributing the organ-forming substances of its interior. He is now engaged upon this and allied problems. No effects of the waves have been noted that could be clearly traced to an influence on chemical processes in cells. The phenomena in living organisms, apart from temperature rise, are connected with mechanical effects, the most striking of which might be best described as "intracellular stirring."

Mr. Loomis, who is a physicist, perfected the new microscopic apparatus for the production of the super-sonic waves, while Dr. Harvey has been studying the effect of them upon cells from the physiological standpoint.

EFFECT OF ACTIVITY AND FOOD ON BLOOD CONSTITUENTS

THAT food, especially protein food, causes an increase in the number of leucocytes in the circulating blood has been quite generally accepted as a fact since first reported by Moleschott in 1854. In the 1927 edition of Dorland's "Medical Dictionary" it is stated that leucocytosis "occurs normally during digestion." In view of these circumstances the recent work of Dr. Walter E. Garrey, professor of physiology at the Vanderbilt University School of Medicine, is of especial interest. In his experiments he finds that even a meal selected particularly for its high protein content causes no alteration in the number of white blood cells in the circulatory system. He believes that other opinions in this matter fall short of proof because the conditions under which the leucocyte counts were made fail to exclude the effects of factors which in his experience cause continuous variations in the number of circulating leucocytes. These variations become evident when successive counts are made; they may amount to several hundred per cent. depending upon the activity of the subject. The more careful the technique, the more certainly will these variations appear and reflect the physiological activity of the individual. They disappear, however, if the subject is placed in a recumbent posture and remains physically and mentally in a condition of rest. Furthermore, in about an hour of this recumbent rest the leucocyte count will have fallen to its lowest physiological level, a level which is practically as low as that before rising from a night's sleep. This level is maintained with surprising constancy and is referred to as the *basal level,* and in general is between 5,000 and 6,000 leuco-

cytes per cubic millimeter of blood. This is in striking contrast to the activity level of 9,000 or 10,000 usually found in laboratory workers or other individuals going about their ordinary activities.

The "basal level," then, is a condition with which one may compare other states and by this reference determine the effects of any single variable which may affect the leucocyte count. Dr. Garrey finds that his extensive data indicate conclusively that the ordinary morning meal had no apparent effect upon the activity level of subjects when they presented themselves at the laboratory, but more significant was the fact that when these subjects assumed the recumbent posture the leucocyte count dropped according to rule and the basal level for the individual was reached in approximately an hour, and remained at this low level without variation for several hours provided the subject remained undisturbed; there was no rise after two or three hours, *i.e.*, there was no evidence of a digestive leucocytosis. In like manner a second mid-day meal in no way affected the return of the leucocyte count to the low basal level.

If one subject is given a heavy meal and the other goes entirely without food, the two show exactly the same variations of form if the individuals act in the same way, *e.g.*, lie down at the same time and rise for the ordinary activities of the day simultaneously. There is evidently no difference in level attributable to food.

What Dr. Garrey believes to be crucial experiments were conducted in the following way. Subjects, without breakfast, came into the laboratory. The first leucocyte counts showed the high activity level of about 9,000. The individuals then lay down and leucocyte counts were made every fifteen minutes for several hours. Within an hour the count was between 5,000 and 6,000 and the subject was then fed, in one series a protein meal, in another a carbohydrate meal of pancakes and syrup. Proteins are supposed to be especially potent in causing digestive leucocytosis and the subjects received two pounds of beefsteak, four eggs and two slices of toasted bread without fluid. In no single instance was there evidence of the slightest increase or variation in the number of circulating leucocytes, although the counts were continued for as much as four hours. If, however, the subjects for any reason assumed the erect posture there was an immediate increase due to postural change and activity, but upon assuming the recumbent posture the count fell again to the basal level within an hour.

Dr. Garrey concludes that there is no true digestive leucocytosis, and that the variations that have often been reported must be attributed to other forms of physiological activity which cause a vascular shift resulting in a redistribution of the blood and of the leucocytes already in the circulatory system.

THE SCIENTIFIC MONTHLY

OCTOBER, 1929

THE SCIENCE OF ICE ENGINEERING

By Professor HOWARD T. BARNES

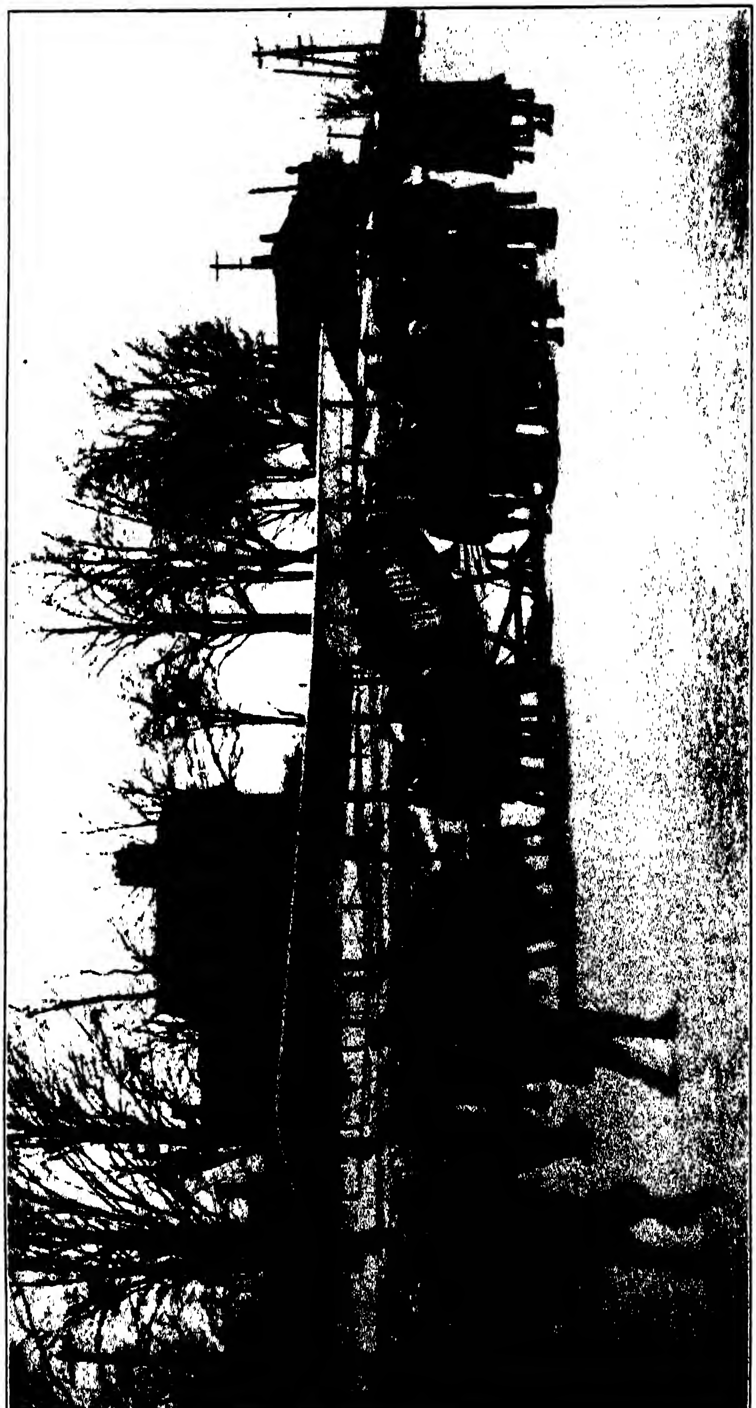
MCGILL UNIVERSITY

THE science of ice engineering has as its object the control of ice formations in rivers and lakes, and the prevention or removal of ice jams; the assistance of winter navigation; the control of snow and frost when and where desired; the assistance in the winter operation of power houses; the opening of channels through pen-stocks or power canals, and, in fact, to consider means by which all ice troubles may be better understood and finally solved.

The tremendous cost of ice and snow to this country may be summarized as follows: ice jams with disastrous flooding; shutting down and crippling of power plants; closing of canals and river systems in the north; delays caused by the snow and ice in the operation of railways, motor cars and aeroplanes, and the destruction of telephone and telegraph lines from sleet and snow, etc. To save even a small fraction of the loss in these instances would result in many millions of dollars and certainly justifies the attention and study which may be devoted to it. For the past thirty-five years it has been the writer's contention that a proper scientific study of ice would result in a method for overcoming and minimizing the disadvantages to all northern countries. As the population increases it becomes more and more important to consider these questions, since the full development of the northern areas of the world must depend upon the proper control of ice conditions. While we do not see, at present, any means of altering the climate of the world, we can, by understanding nature's method of ice control, find means for relieving and tempering these facts.

In order to obtain an idea of the fundamental principles of this new science, it is necessary to consider briefly something of the constitution of water and the nature of ice. Röntgen in 1894 was the first to point out that the physical properties of water indicated that it contains ice in solution. It was not until the studies of Sutherland, published in 1910, that a working theory was established showing that the properties of water could be interpreted by assuming that the pure substance known to the chemists as H_2O could exist only in the form of dry steam or vapor; that liquid water was a double molecule or $(H_2O)_2$, and that ice was a triple molecule $(H_2O)_3$, which forms at once as an associative product. Water, then, must be regarded as the mixture of two liquids, the proportions of either depending on the temperature.

As the chemist uses H_2O very freely as a symbol of water, or hydrogen oxide, for international convenience Sutherland gave names to these associated molecules. The simple molecule was called hydrol; the double molecule, dihydrol, and the triple molecule, trihydrol. Dry steam is, therefore, pure



ICE ENGINEERING

IS GREATLY AIDED BY THE AEROPLANE. VIEW OF PLANE USED BY DR. H. T. BARNES, IN 1925, DURING ICE STUDIES FOR THE HYDROELECTRIC POWER COMMISSION OF THE ST. LAWRENCE RIVER.

hydrol; ice is pure trihydrol, and water as we ordinarily know it is a mixture of dihydrol and trihydrol.

Evidence of the theory of the constitution of water is had from the studies of the density of water, optical behavior, specific heat and viscosity. Ice in its solid form has a density of 0.9166, and if it could melt and expand without dissociation like a metal, the density of the liquid ice at 0° C. ought to be about 0.88. Sutherland calculates the varying proportions of one ingredient with the other resulting as follows:

0° C.	37.5 per cent. liquid ice
20° "	32.1 " " " "
40° "	28.4 " " " "
60° "	25.5 " " " "
80° "	23.4 " " " "
100° "	21.7 " " " "
198° "	16.5 " " " "

At the critical temperature, which is about 368° C., water must consist of nearly pure dihydrol, or, in other words, the ice in solution nearly disappears at the critical temperature. It seems evident that the melting-point of ice is not a true physical melting-point but a temperature of dissociation unlike the physical melting-point of other materials.

Colloidal Ice

In considering water as a colloidal solution of ice, there is no microscopic evidence to show colloidal ice particles in water at temperatures above the freezing-point. At the freezing-point, however, the colloidal particles of ice form complex groups of sufficiently large dimensions to be distinguished under the microscope. When a fall of temperature takes place, even the smallest fraction of a degree below the freezing-point, the exceedingly viscous particles of colloidal ice rapidly agglomerate and pass to the true ice crystal.

Microscopic photographs of ice particles as they precipitate from the water show that they are disk-shaped and devoid of crystalline form. The particles, if undisturbed, grow into a form similar to a snow crystal. Various forms of ice are met with in nature, all of which have their explanation in this colloidal theory.

Frazil Ice

In all running streams of open watercourses the most troublesome form of ice is known as "frazil." To the water-power operator it is exceedingly troublesome. With the first cold weather in the autumn when the water comes to the freezing-point there is often a very large and sudden formation of frazil. The explanation of this is exceedingly simple when we realize that the entire body of the stream is nearly 40 per cent. colloidal ice before freezing and coagulation takes place, when the temperature of the water has dropped a few thousandths of a degree. This mass of ice rapidly coagulates into streamers and subsequently into lumps and large clots which are carried in the current to great distances. So abundant is this formation that within a few minutes the whole stream may appear to be loaded with sand. During this time of supercooling these clotted masses of colloidal ice grow rapidly and freeze to any object with which they come in contact.

So delicate is this balance of temperature which determines the sticking properties of this ice that a change of a thousandth of a degree is sufficient to prevent the formation or facilitate the growth of this ice. This delicate balancing of the forces of nature is easily explained when we understand the true nature of the water structure and that the freezing-point of water represents a chemical change rather than a physical one.

During the processes of formation the streamers and curtains of frazil ice form throughout the whole body of the water as fog is formed in air. It occurs with the same suddenness as fog and it very closely resembles it. It is dispelled

THE FIRST THERMIT HEAT UNIT
USED IN LOOSENING AN ICE JAM AT WADDINGTON, N. Y., IN 1925. DR. H. B. FABER SHOWN ADJUSTING THE IGNITION WIRES. DR. FABER ASSISTED IN DEVELOPING THESE UNITS.

almost instantaneously by the light of the sun and becomes very sensitive to small temperature changes in the water.

The light of the sun produces a direct action on the ice particles as well as an indirect action on them by warming the water. There are two ways that the frazil fog can be dispelled: one is through this direct action of radiant energy destroying the agglomerating properties of these colloiding ice particles; and, second, there is the action of the heat in warming the water, elevating the temperature, and thereby mechanically acting on the particles of ice by melting them. Radiant energy, such as supplied by the early morning sun, will loosen solidly frozen ice crystals and cause small ice particles to disappear.

Limited Ice-forming Power

Water may be exhausted of its ice-forming power, as has been proved by experiments recently conducted in our Ice Research Institute at Morrisburg, Ontario. In these experiments water in a tank was cooled at a temperature ten to fifteen degrees below freezing. After the expiration of a certain length of time ice was extracted and measured and the water allowed to produce fresh ice for a further period.

As an example of what happens, the result of one experiment showed that the first half hour yielded a full pail of ice. It required, however, a whole hour afterwards to produce another full pail of ice. Two hours more were required to produce a third of a pail. For four hours afterwards no ice was produced. This extraordinary result can be explained on the colloidal theory, but it is difficult in the short space of this article to go into the theory adequately. It is evident that a nucleus is required for the colloidal ice mass, and after exhausting these nuclei, the formation of further ice is rendered difficult. This subject will be treated fully elsewhere.

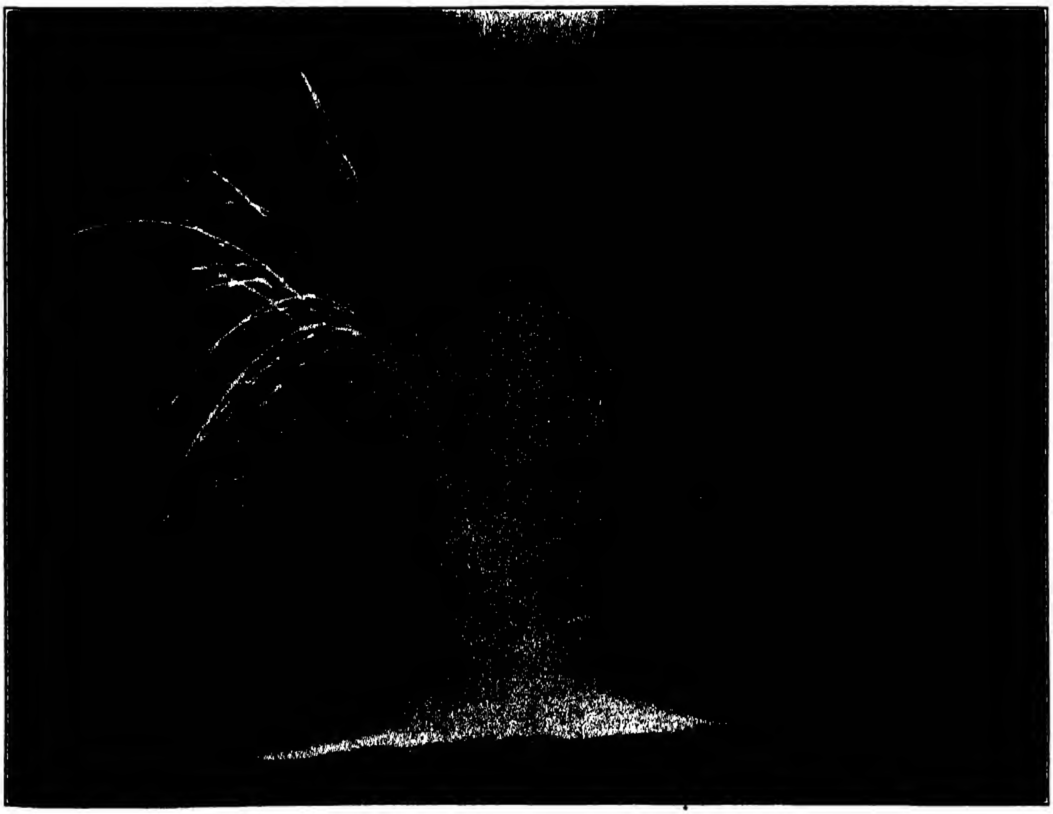
Warming Water to Obtain Ice

The passive state of water can be explained, also, on the ground that there is a time required for the restoration of the trihydrol in solution and at the temperature of freezing it is considerably slower than at higher temperatures. The active, or ice-forming state of water may be restored immediately by warming the water to room temperature and then cooling, indicating that the equilibrium is established quickly at higher temperatures. We have, therefore, the interesting anomaly of producing ice in water by warming it.

Anchor Ice

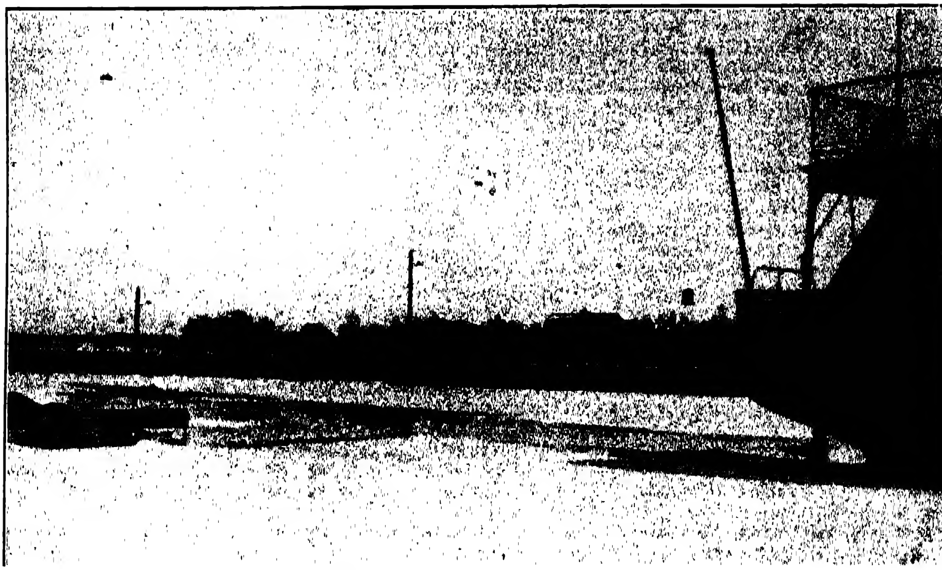
Anchor ice occurs in rapids and streams up to a depth of thirty feet, and depends upon the clearness of the water and the rapidity of flow. It is exceedingly sensitive to daylight, and such formations as occur at night are immediately relieved by daylight. This anchor ice is formed in rapids even when the temperature is considerably above the freezing-point. It forms more slowly with greater cooling in deeper water.

Correspondingly, the melting of this ice is more rapid in shallower streams on the advent of daylight and during very cold weather the anchor ice may remain for several days on the bottom in very deep streams. Thus, we will have on a river a run of anchor ice in the morning from the shallower parts and in the afternoon from the deeper portions, establishing thereby a very valuable dis-



THERMIT DESTROYING ICE

Disintegration of a solid block of ice, two feet cube, by the heat from two and one half pounds of thermit. Phosphorescent ice and heated hydrogen gas rising to seventy feet.



CALCIUM CHLORIDE OPENS CHANNEL IN ICE FOR MORRISBURG FERRY

ANCHOR ICE
DEPOSITED ON A PIECE OF WIRE FLY SCREEN UNDER WATER.

tribution of ice flow in an open stream, for the greater abundance of ice from the shallower portion has passed before the ice from the deeper portion rises to cover the surface.

The formation of surface ice is a study in itself and can not be fully treated here. Its growth is exceedingly slow after it has achieved a certain depth, and it is interesting to observe the formation of the crystals of this ice by the accumulation by layer after layer of ice disks on the under side very much like stacked Chinese coins. Very old surface ice gradually becomes coarser in structure, owing to the fact that the large crystals consume the smaller ones. This is noticed also in old glacial snow accumulations. After many years of continual cold the glacier becomes coarse-grained and the snow much more granular in structure.

Of the factors which contribute towards the formation of ice, undoubtedly the most important is terrestrial radiation, causing ice growth by reason of the fact that water is a perfect radiator of heat, and in winter loses its heat faster than it receives solar energy. Wind agitation, surface disturbances in rapids and waterfalls, deficient humid-

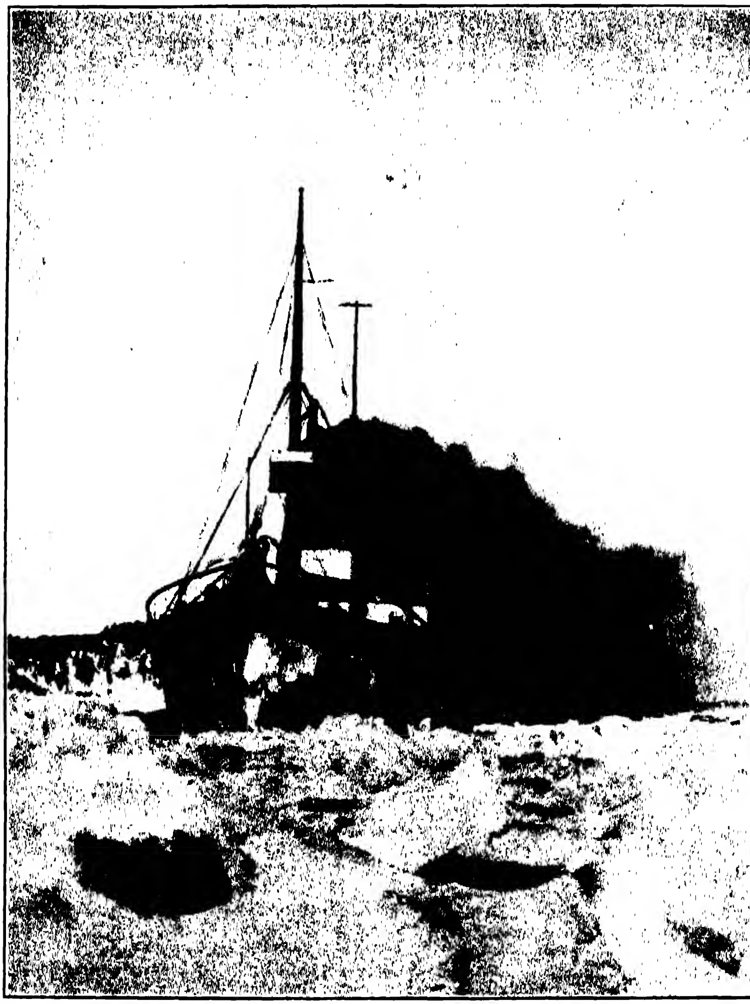
FLOOD LIGHTS ALONG RIVER TO PREVENT ANCHOR ICE AND TO LOOSEN FRAZIL

ity and exposed surfaces all contribute their influence to abstract heat and assist the growth of ice.

Counterbalancing these we have the forces of nature which retard the formation of ice, such as solar radiation, radiant heat, reduction of exposed surfaces, warm rain and high humidity. Light is the most active agent, and it is the light rather than the heat of the sun's rays which is most effective, especially the rays of the rising sun which coming through a clear atmosphere can penetrate deep into the ice and water. As soon as the sun rises in the morning the ice production almost stops, and that which has been formed during the night along the bottom of the river rises and floats on the surface.

In developing artificial methods of ice destruction it has been found that the greatest success has been obtained by methods which are similar to those employed by nature. The exercise of brute force on ice has resulted in a distorted impression of how ice should be handled. By the river-man the use of dynamite has always been resorted to in times of emergency, but it has been found conclusively by expert experimentation that high explosives such as dynamite, T. N. T., black powder and nitroglycerine are of very little value, as most of the energy that is generated is shot up in the air, which merely serves to compact the ice more. While very spectacular in effect, all this energy wasted in the air should properly be used under the ice in destroying its strength.

In 1925 the writer came to the conclusion that heat-producing chemicals such as thermit are more efficiently employed.



A NORTHERN ICE PACK
A GOVERNMENT ICE-BREAKER WORKING THROUGH PACK ICE.

Thermit, which has come to be known generally in its work with ice, is not in any way explosive, but when properly ignited reacts vigorously, generating very high temperatures and producing extremely hot liquid steel. This heat causes the ice to split into its constituent parts, hydrogen and oxygen, with explosive violence, and thus the energy of the reaction is confined and held underneath the surface. The oxygen is mostly fixed by the iron of the thermit to form oxide again, while the hydrogen is liberated as a very hot penetrating gas which burns in the presence of air on top of the ice in a sheet of flame. Literally the ice blasts itself.

The writer has developed a number of methods of attack which are based on scientific physical study. These methods appear capable of dealing with any ice accumulation, when relief is necessary to avoid flood damage or stoppage of a power-house. No set rule can be given, however, as each problem is a study in itself and requires a particular

treatment. The skill of the operator, or ice engineer, is the important factor in its success.

Time is a determining element in ice-engineering work, and remedial measures should be undertaken before the trouble occurs rather than heroic efforts to release an ice jam once it has formed. A quiet safe method of destroying ice in a stream at restricted points where jams are liable to occur results in the disappearance of ice long before the spring breakup occurs.

It is possible even to destroy the ice-forming quality of the water before the ice is formed and thereby keep the water in a passive state, but this new method of ice technique is now being developed and it is too early to say what may result.

Materials Used in Destroying Ice

Besides thermit, which is a mixture of oxide of iron and metallic aluminum, there are other chemicals used in the treatment of ice, such as calcium carbide, calcium chloride, sodium chloride, all of which have a powerful action in rotting and destroying surface ice in the coldest weather, leaving it weakened to such an extent that it offers no resistance to an ice shove. A field of ice can be so treated that definite lines of weakness can be established in any prescribed manner. Young ice can be destroyed in a few minutes, and channels opened in proportion to the economic desirability of such work. Charcoal, cinders, lamp black, sand and gravel are also very useful in their way of drawing the sun's heat and aiding in the rapid destruction of surface ice when correctly applied.

In every case where ice of a river is treated during the winter months by these methods the spring break-up may be hastened at least two to three weeks.

The writer has developed recently a new material called "solite" which can be dropped from an aeroplane over a crucial point in an ice jam. Solite is very effective in treating these congested areas not easily reached. It requires no wires or batteries to set it off and may be delayed to any extent that is required, hence it is of very great use in aeroplane work.

Before undertaking a piece of ice-engineering, all information should be obtained by a general survey of the section to be treated; the accumulation of existing data, and comparison with previous records, where they are obtainable; the depth and nature of the ice and the flow of water in the region under consideration; the lines and points of weakness in the ice mass to be considered.

If this work is undertaken early in the season so that the accumulation and growth of frazil is kept away from the surface ice and the water allowed to flow under the ice, serious ice jams and the resulting flood and loss of property can be avoided.

In the same way, if engineers in constructing dams and power-houses would take into consideration their ice hazards, and would employ scientific methods for overcoming them, much of their trouble could be avoided and a great deal saved in the cost of construction. It is estimated that many millions of dollars are lost annually from power structures owing to the want of attention to winter operation.

Many lines of work have yet to be attacked, but the great success already achieved by the new methods is very encouraging for the future development of ice-engineering, and from the keen interest with which the public has followed its development, it is apparent that people are beginning to realize that we will not inevitably have to submit to this tyrant of the north, but that it, as well as many of the other great forces of nature, can be controlled and converted to our use and benefit.

THE HOPKINS MARINE STATION OF STANFORD UNIVERSITY

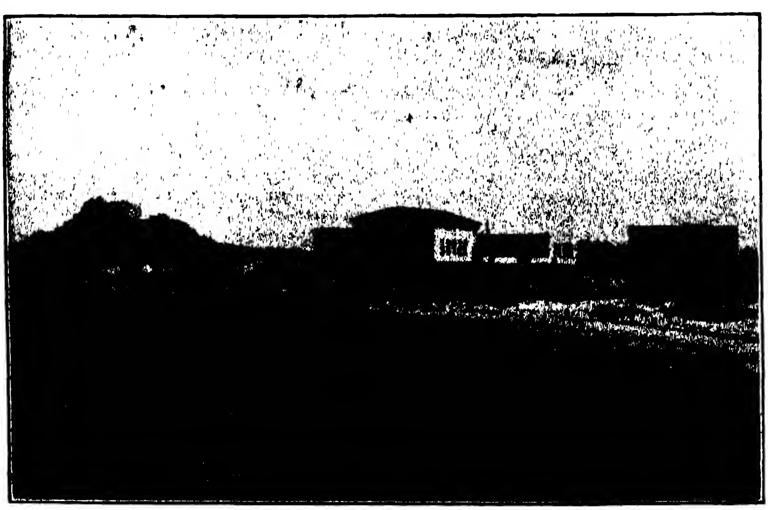
By Dr. W. K. FISHER

DIRECTOR OF THE HOPKINS MARINE STATION

ROBERT LOUIS STEVENSON aptly compared the curve of Monterey Bay, California, to that of a fish-hook, with old Monterey bordering the sheltered bight at the south. In the adjacent town of Pacific Grove, near the "barb," is the Hopkins Marine Station. Hard granitic rocks interspersed with short beaches characterize this portion of the coast, as well as the rugged littoral to the south. For forty miles to the north of Monterey is a long sweep of sand representing the shank of the hook. In places back of this are quiet meandering sloughs with zostera and a rich permanent fauna of mud-loving animals. Low, pine-clad hills separate the harbor of Monterey from Carmel Bay, a few miles to the south.

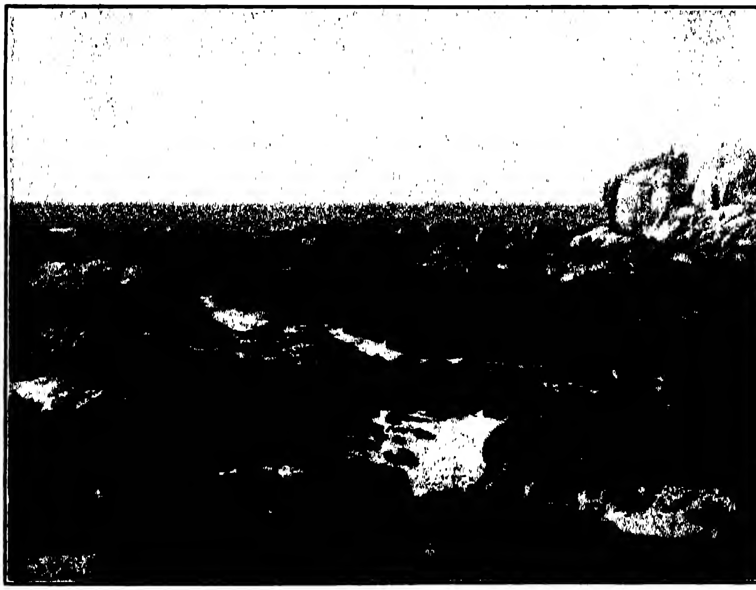
Four names are inseparably associated with the founding of the Hopkins Seaside Laboratory in 1892: Timothy Hopkins, David Starr Jordan, Oliver Peebles Jenkins, Charles Henry Gilbert. Back of the obvious desirability of a marine biological laboratory in connection with a new university of great promise, was the example of Anton Dohrn's Naples laboratory, which had greatly impressed Mr. Hopkins, and the Penikese experiment of Agassiz in which Dr. Jordan played a part at a formative stage of his career. The combination of these four men was a peculiarly happy one—all young, enthusiastic, each playing an essential part. So the idea started. After thirty-eight years it is significant perhaps that the Hopkins Marine Station more nearly resembles the Naples Station than it does any of its other predecessors—but with features essential to its organization as part of a university. One of its buildings bears the name of Agassiz' son, and it is to be hoped that those responsible for leading the younger generation have not forgotten the Penikese ideals so ably interpreted by Dr. Jordan.

The present station dates from 1916 and is due to the vision and energy of



THE HOPKINS MARINE STATION

THE JACQUES LOEB LABORATORY AT THE LEFT.



LOW-TIDE AT THE STATION POINT

President Ray Lyman Wilbur, who was himself a student at the Seaside Laboratory. The land and the two wooden buildings of the original institution became quite inadequate. A new site was chosen, which by subsequent purchases was augmented to about eleven acres. This comprises all of what was formerly known as China Point, from the presence of an old and picturesque Chinese fishing village, wiped out by fire in 1903. Near this site stood the old Hertzstein Laboratory in which Jacques Loeb continued work begun at the Hopkins Seaside Laboratory.

In 1917, while the first building was

HIGH-TIDE AT THE STATION POINT

COAST AT CYPRESS POINT, NEAR MONTEREY

under construction, the present name was adopted. This unit, recently designated the Alexander Agassiz Laboratory, is of reinforced concrete construction, three stories in height and approximately forty-three by eighty feet over all. In the summer of 1928 a second unit, known as the Jacques Loeb Laboratory, was completed from funds donated by the Rockefeller Foundation. This is also of reinforced concrete, and as shown by the illustration consists of a central portion of two stories flanked by two wings of one story enclosing three sides of a front court, the over-all dimensions being ninety-five by one hundred fifty-two feet. The building is designed for permanent research in

THE HOME OF SURF FISHES AND SAND-LOVING CRUSTACEA AND MOLLUSKS

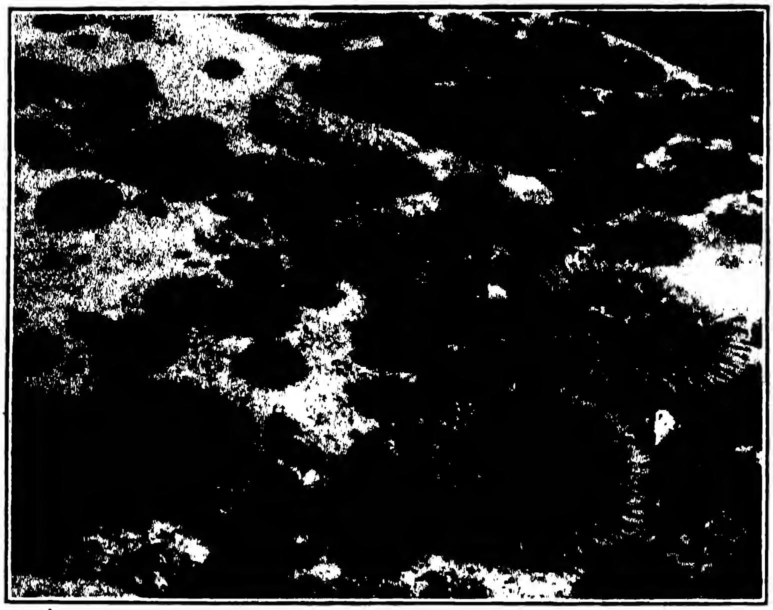
physiology, experimental morphology, biophysics, biochemistry and bacteriology. As a general principle, large specialized laboratories are equipped rather than individual work-rooms, although seven private rooms are available.

The general facilities which are present in nearly every laboratory include: pressure and suction air; alternating and direct current up to 200 volts; battery current to 90 volts. In the large laboratories provision is made to vary the current at almost every outlet, and specially constructed hoods with outlet controls increase the usefulness of the rooms. Sea-water is conducted through antimony-free lead pipes to a reservoir of 10,000 gallons' capacity situated on an elevation of rocks whence it is fed by gravity to the aquarium tables and sea-water outlets in the laboratories. In the construction of this system the use of copper and metals other than lead has been avoided. All aquarium tables are equipped with several air pressure outlets. One room is designed for permanent set-ups, such as potentiometers. There are five dark-rooms, one for general photographic use, three for spectroscopy, polarimetry and photometry, and one heliostat room which derives its light directly from the roof of the building. The principal laboratories and work-rooms are supplied with sea-water, hot and cold, fresh water, distilled water, gas, in addition to the current and air outlets mentioned above.

THE RUGGED COAST SOUTH OF MONTEREY BAY TEEMING WITH ROCK-LOVING SPECIES

The older building, the Alexander Agassiz Laboratory, houses those of the staff concerned with the hydrobiological survey of Monterey Bay and with the more traditional lines of research in zoology and botany. This building also contains the general laboratories in which most of the undergraduate classes are held during the spring and summer quarters.

Since 1918 the station has been open during the entire year, and it now maintains a resident staff of eight specialists in addition to three technical assistants, a secretary and a mechanician. The permanent staff is augmented during the summer by members of the school of biology of Stanford University, and



PURPLE SEA-URCHINS AND GREEN SEA-ANEMONES
A CHARACTERISTIC COLOR COMBINATION.

usually by a few biologists from other institutions. The staff tenders facilities to visiting investigators, furnishes graduate and undergraduate work in biology and maintains a permanent program of research.

During the last two decades it has grown increasingly evident that the biologist can no longer pose as a physicist, a chemist, a bacteriologist; nor is a successful anatomist, embryologist, taxonomer and oceanographer likely to reside in one person. A research institution committed to hydrobiology, oceanography and the multifarious ramifications of experimental biology can not function without the aid of specialists.

An enumeration of projects under way or planned for the immediate future would suggest the scattered blocks of a mosaic rather than a finished picture. The research program in a general way concerns itself with oceanic biology. This work includes a hydrobiological survey of Monterey Bay which is being carried out with the cooperation of the California Fish and Game Commission. Special attention is being paid to the relations between the organism and its environment, including a consideration of the composition of sea-water in relation to equilibrium with solutes. The developmental histories of fishes having pelagic eggs is being given major consideration, as is also the ecology of plankton organisms. A factor of prime importance is the close proximity of depths as great as a thousand fathoms. It is therefore confidently expected that the physiology of pigments and luminescent matter of deep-water organisms and certain features of the ecology of these same creatures will be available for study in the near future. The physiological program comprises the characterization of the environment in relation to varying groups of organisms, more especially those living in an abnormal environment. The project includes the determination of the limiting conditions of life and of various extreme circumstances in order to learn something about the meaning of the so-called normal environment of the ocean. General problems connected with marine bacteriology occupy the attention of a

specialist, while another is concentrating on a spectroscopic study of various natural pigments. Band spectroscopy, especially when applied to the living cell, has proved to be a powerful tool in biological research. Work in progress in organic chemistry includes a study of planktonic oils and fats, their decomposition products, both aerobic and anaerobic—in short, their position in the natural cycle of the ocean.

The proverbially rich fauna and flora which are readily available at low tide offer big returns to the investigator and beginning student alike. With such an environment the dyed-in-the-wool zoologist and botanist are at an advantage. The wealth of forms is in part due to the hard granitic rocks, the diversity of exposure, the cold water and the rich assemblage of micro-organisms of the open sea. Many animals are permanently attached, or have dug in, and must have their food brought to them by the water. Groups which especially give character to the fauna are the sponges, anemones polyclad, nemertean and annelid worms, sea-stars and sea-urchins, bryozoans, mussels, chitons (upward of fifty species) and gastropods, the higher crustacea and compound tunicates. Dorid nudibranchs are conspicuous for their size and brilliant color. The plankton of the bay runs the gamut of the animal kingdom from a varied mob of protozoa to salps. Diatoms are very abundant, and the growth of shore algae is lush, often a nuisance to the zoologist, including a wide range of forms from the giant kelps to tiny species which grow upon them as do epiphytes upon tropical forest giants.

Excellent material is available for research in cellular biology, normal and controlled development, experimental morphology, anatomy and taxonomy. There are so many problems in the natural history of shore and plankton forms, both invertebrates and fishes, as to defy enumeration. Fundamental taxonomic work remains to be initiated before much good material for experimental work will be available. As the hydrobiological survey progresses opportunities will increase for highly desirable studies on the ecology and special physiology of deep-sea plankton organisms. The harvest is big but the harvest hands are few!

THE MONTEREY CYPRESS

THE DEVELOPMENT OF AGRICULTURE

By Dr. WALTER HOUGH

THE U. S. NATIONAL MUSEUM

THE period of culture at which men gather together into communities is necessarily variable. It will be seen that it may depend upon the stage of advance, natural mental or physical qualifications, favorable or unfavorable environment, war, disease, repression by neighboring peoples and other causes that may be recognized. With all that can be placed on the debit side it is found that overcoming all suggested obstacles the condition of solvency appears with agriculture. The difficulties of the struggle upward perhaps can never be known and it is necessary to gather illuminative data from tribes that might or might not progress on lines of advance. Therefore a long period may be predicated before man reached a suitable field where agriculture could be developed. There enter here also the requirements of the environment suitable for the cultivation of the grain and food plants in possession of the farmer.

Law of Human Needs

One portion of the law of human needs is that man must have food on the spot. Obeying the law, man has subsisted on a variety of diets, depending upon the place where he is at the time, taking nourishment from the game of the waters or land, or being frequently a vegetarian of a rather strict sort. Thus when man's diet is examined into it is found that he follows out what physiologists say about the evidence of his teeth, that he is omnivorous. When the need comes strongly to the front anything edible is acceptable. For this reason the subject of diet is important in observing the habits of the races of man. Mostly this is a curious and somewhat superiorly amusing topic except to scientists who are compelled to look beneath the surface for the explanation of, for instance, how and why man became a farmer.

It is seen at once that not all men became tillers of the soil and that opportunity did not come uniformly to the race, because many tribes in the world have not yet graduated to the ancient art of farming. This is because, as will be brought out, there were so many hindrances on the way up.

While it is evident that the early farmers began agriculture on continental land areas, and as pointed out by Payne, of Oxford, under semi-desert conditions where the repressive effects of exuberant vegetation are not present, its discovery was greatly delayed when we consider the migrations of groups of men through a long period, before the proper environment for the practice of this art was reached. In the early period we must imagine that environment was not yet effective as a factor more or less potential in its interactions of man and conditions. It is logical to suppose that man migrated in search of environments favorable for his well-being, moving on and leaving fractions that were stationary on grades of food supply below the agricultural level or that present mixed phases of agricultural and feral subsistence. Examples in point are a primitive dependence upon fruitful trees and other plants furnishing food, fiber and other necessities, this phase exhibiting what may be called unconscious cultivation. The agave and cassava were important subsistence plants in primitive America long before maize and it is probable that the date palm growing much antedates the use of any cereal.[1]

[1] "The Palm and Agave as Culture Plants," Internat. Cong. Americanists, Quebec, 1906. pp. 215–221.

Conditions of Subsistence in Pre-agricultural Times

At no time and in no environment is observed a purely animal subsistence. In ice and tropical areas, if it is allowable to cite the habits of peoples living in the high north as evidence, the food intake was mixed animal and vegetal. This fact is reflected in the mixed dentition of man and is also evidence of the development of practical means to insure the perpetuation of man by habituating him to subsist in environments unfit for other animals confined by nature to a type food supply.

The food supply of the native inhabitants of a north and south extending hemisphere, as the New World, is readily analyzed.[2] The east and west lying Old World presents different problems more complicated by nature and more varied, owing to the phases of domesticated animals and the possession of the major grains.

Nature being so tremendously prolific in things not needed by man and chary of things he can use for the higher economics, it appears that root crops, mostly poisonous without treatment by fire, do not furnish a reliable basis for a populous or permanent civilization. It is true that we find in the West Indies and a vast area in South America what may be termed the cassava culture based on the root of the *Manihot utilissima*, but even in localities where maize is an adjunct there has been produced no civilization of importance in the progressive history of man.

Similar conclusions must be stated in regard to the races subjected to meat and fish diet. These, it will be observed, present interesting phases in the dietary and economics of various races, but aid little in the floristion of culture. Such diets are characteristic of some of the side-tracked sections of humanity compelled to observe the food law of nature and to glean with hard labor their isolated lands and sea for something to eat.

Lines Leading to Agriculture

Presuming largely that agriculture became effective at the stage when the populations of favorable regions reached a density that demanded a stable basis of subsistence, it is possible to affirm that the art of cultivation arose comparatively late in the scale of human progress. In fact, agriculture began, so far as the definite cropping of cereals is concerned, in the Neolithic, the earliest date assigned to this period in any area being 8,000 B.C. Before this time humanity did not depend upon this basic industry of farming. Agriculture, then, may be said to mark the beginning of permanent and incalculable progress.

As with inventions that are seen complete in the hands of man, one is tempted to conjure up some genius who discovers agriculture, but on reflection this is too easy, not to say the lazy way, omitting the long and painful steps of progress that must be taken before an invention can be perfected. As to the origin of invention, Greek philosophers and other wise men must have waved their hands at the crux and attributed it to Daedalus or like worthy.

Development of Food Plants

Agriculture had a beginning, though its earlier stages are not recognizable in the terms of present agriculture. It is necessary to regard the progress not as a definite aim, but a development involving many factors, some of which are pointed out, and coming to a consummation recognizable as agriculture with the cultivation of grain-yielding plants such as rice, wheat, oats, barley, rye and maize, and the less economically important but highly valued leguminous plants as beans, peas and the like. The obscurity covering the history of the domestication of these plants is not rivaled by that surrounding the "lost arts of the ancients" of literature.

[2] "Handbook of the American Indians," Bull. 30, Bur. Amer. Ethnol., Article: "Food."

No attempt is made here to follow out a theoretical scheme as to the development of plants for economic use. It is understood that plants capable of agriculturation were finally selected and planted and brought forward in yield, pursuing the methods and deadwork of clearing, tilling, watching, representing the great labors antedating the harvest. It is surmised that the cereals were selected during the period of wild harvesting and that plants showing fruitfulness and perhaps a desirable flavor were planted when the agricultural phase of culture began to take on importance.

The question whether the agricultural method arose independently with each basic cereal can be with confidence answered in the affirmative.

On this topic the agriculture of maize in America is a conclusive argument. This strictly American cereal was brought to economic perfection by indigenous methods which conform to those applied to cereals in the Old World. The origin of maize cultivation in America is quite as obscure as is that of such basic crops in other parts of the world. Here in the western continent the rational developments observed elsewhere are evident in the rise of advanced civilization under the tutelage of maize.

Selection of seed is well understood by aboriginal agriculturists still retaining the older phases of the industry. This feature was no doubt learned quite early, and largely by it agriculture of grains acquired more importance in furnishing requisite amounts of a chief staple that could be stored from harvest to harvest. The experimental selection of seeds over a long period gives in the result what Burbank accomplished in a few years by using the scientific mind on the experiences acquired by plants in the course of their life history.

Environmental Conditions

In the laboratory of nature plants come to represent the various reactions arising from favorable and unfavorable correlations in the environment. They reflect in their structures the good or bad treatment they have received in the past. In associations with man undesigned contacts are observed to be favorable to plants. About the habitations of man in unused spots weeds flourish more luxuriantly than in their natural areas. In an enclosure, vegetation normally repressed by soil or animal enemies flourishes and, as around the domicile, begins in some cases to leave off its feral protective devices. In a garden competition of wild plants with the desired crop becomes at times fierce, especially in regions where the rainfall is depended upon to get results.

Personal observations in Mexico of village communities give the impression that in the scattered houses each with its little plot of ground we have a picture of the early grouping of man, a laboratory favorable for carrying out designed and unintentional experiments with plants. In one place a spineless cactus (Opuntia sp.) was observed in a dooryard, a proof of Burbank's thesis that plants react to protection. In some such condition the ancestor of maize may have shown variations which attracted the early gardeners. About 1914 the teosinte plant of Mexico was put through a short course by Burbank and made to produce ears of naked grain maize.

Plants coming into close contact with man begin to exhibit potentialities of usefulness not disclosed by the same species in a feral state. The plants that will be useful begin to show variations in the way of better fruits and the casting off of disadvantageous acquired protective devices.

At this period in human culture characterized by a relatively great progress man focused upon plants the same knowledge which he had derived from his observations on the habits of animals, that is, had collected the data necessary for their capture. In the phase when

animal subsistence was important the characteristics of animals were known, being essential to his existence. It may be said that the animals that would subsequently be domesticated were already known on account of their habits to men of the loosely classed hunter stage.

Incidentally, the uncivilized tribes are sometimes not given credit for the vast body of knowledge that they possess on the plant life of their environment. Only in recent years has this line of scientific inquiry been given the attention, not at all adequate as yet, which it demands.

The Hopi Indians have what seems to an outsider a pretty conceit when they name a plant "the Mole his corn," "the Field-mouse his corn," and the like, but in reality there is disclosed here the keen observation of the Indian on the natural subsistence of animals. How much this has aided native men in the selection of plants is speculative. On the other hand, the relation of animals and plants is an interesting study, in regard especially to the modification of species through the ministrations, or undesigned agriculture, of animals. It is evident that plants have been brought far along the road by other forms of life. When man took them up for practical purposes beyond any previous uses, plants had diversified in such characters as fruitfulness through the aid of insects and other helpers in the wonderful partnerships of nature.

It is probable from the above considerations that agriculture, which is now regarded as productive principally of cereal crops, was confined originally to garden plots to which plants more or less useful to subsistence were intentionally brought and tried out. Here it may be conjectured most of the vegetables, small fruits, trees and so forth accompanying farming were developed further. The cereal destined to bring the crop of the highest economic importance to the greatest number of mouths doubtless derived from but did not supersede its humbler companions.

Methods From Hoe to Plow Stage

It is understood that there will necessarily accompany agriculture from the primitive stages to the most advanced certain essential tools. These tools, representing with reasonable clarity the progressive stages of agriculture, are the digging or planting stick, the hoe and the plow. While these are concerned with getting the crop in the ground, caring for it, and are among the myriad of devices growing around the needs of agriculture, they are tools of almost universal use, affording a means of grading the races of planters.

The digging stick came into agriculture from early periods when it was of general utility for digging out game from burrows or other excavating work and for many other purposes, even as a weapon. It is possible that a stick was first aid to primitive man.

In America the agriculture of maize requiring the planting of the seed in hills rendered the digging stick an essential tool peculiarly adapted to this work. The Hopi and other Pueblos retain this primitive tool to this day. Apparently among them the hoe was introduced through the Spanish conquest and found its chief use in clearing the desert fields for planting. An intimate personal possession of the farmer, the Hopi regard this digging stick as a symbol of support and reliance in life and death. The digging stick protruding above ground at the head of a grave denotes a guide for the spirit in making its way from the piled-in earth.

The usual Pueblo digging stick is a stave of strong wood worked wedge shape at one end, and beyond the smooth human wear has no other modification. The Zuni expand the end of the stick into a blade and work out a crutch for the foot in forcing it in the ground. The digging stick here becomes a spade

worked in a standing position, while the farmer sits or squats on the ground in wielding his stick, indicating a more primitive method. In the Salt River Valley the early irrigationists used a blade-like digger, and in cliff dwellings and other sites sword-like digging sticks have been found. A weighted digging stick for getting out roots, the weight being a perforated stone, was used in California and is observed in South America and other parts of the world where root subsistence is important.

In general it may be said that the digging stick is not in the line of the ancestry of the hoe, and the method of use is quite different, the former being a vertically thrust-in and piercing implement and the latter delivering a horizontal blow like a pick or adz.

The hoe is more strictly an agricultural tool adapted to the cultivation of plants in tractable soil. In method it is used more as a horizontally mounted shovel, drawing the earth into the beds or ridges formed in eastern Indian maize culture. It thus suggests the ancestry of the plow. The digging stick proves its usefulness in hard soils and in the obstacles of fire clearings, while the hoe follows in working the loosened earth. It is likely that the breaking of fields for the crops of European-Asiatic grains was exclusively accomplished with sharpened sticks. In archeology the hoe is in evidence only when the material is stone, while the perishable materials, such as wood, bone, etc., have disappeared. Therefore the distribution of hoe culture can not be outlined by the stone implement. Also in many localities the proper stone for making hoes does not occur.

It will be seen that the digging stick and hoe belong to the period of small plot agriculture and only after the increase of population with the accompanying needs does the plow appear. It is evident that the plow comes into use late in the history of agriculture. Its use also marks the beginning of a great period in agriculture. The use of the plow was sporadic in contrast with the general distribution of the digging stick and hoe. Only when the conditions of increase of population and social organization became important enough would the plow be developed. The plow also means more land put into crops, more mass effort and some hitherto unneeded form of traction.

In the picture of wide-spread agriculture before the age of invention it would seem that the plow was invented independently in many places. There is, however, little reason for setting this forth as a scientific conclusion. Nothing like the plow beyond the hoe was ever invented in the western hemisphere. The Europe-Asia-Africa complex is sufficient to explain the diffusion of the plow to these continents together with the conditions for its use as suggested. The rise of the plow in the ancient Near East civilizations is borne out by the conditions which made them civilizations. Improvements on the simple plow are evident in the long stretch of time from the dragged pronged stick to the perfected implement of the present.

Unfavorable Locations

In the spread of agriculture by slow infiltration to favorable land there must have been many disappointments as to soil and the idiosyncracies of plants. The manner of established and combative growths has always been the bane of the general diffusion of agriculture. It is manifest that agriculture does better in nature cleared desert lands than in fields burned or hewn out of the forests. Agriculture in forested lands before the advance of agencies of power in the inventive epoch and hand tools, as the steel ax and grubbing hoe, was a painful and losing adventure. The Mayas coming to Yucatan were forced to employ milpa agriculture, that is, the clearing of fresh areas of forest constantly as the older

fields were captured by vegetation, principally grasses which resisted the primitive methods of cultivation employed by the natives who lacked also grazing animals to keep down the growths. The growing distances of the fields from the population, the transportation of crops and the labor of clearing were met by the Mayas for centuries, during which they developed their wonderful civilization, but eventually these conditions conquered them and reduced them to the jungle state in which they now exist.[8]

There are many examples of such misfits of agriculture like the above which add grievous burdens to the already hard load put by ordinary conditions on the business of agriculture.

Generally by endless experiments agriculture has accommodated within certain limits plants to various regions to which they were not formerly adapted. The tendency to display new characters in plants undergoing cultivation, a habit called variation, has aided in the spread of agriculture.

In this process it is found that plants forced far into variation lose the feral qualities that enabled them to live in their environment and are compelled to depend for their propagation on human agencies which preserve the seed. Many economic plants have been so altered by variation that if it could be imaginable a total loss of seed would render the plant extinct. This applies to grains, but other plants, as the banana, losing their seed by cultivation must be propagated by slips. Thus many plants are dependent possessions of man, who may be represented as repeating the modifications on vegetal life due to insects and these in turn modified by the wonder-working process of variation.

The spread of useful plants may have been influenced by an observed psychology of those engaged in agricultural pursuits. That agriculture was a softening process on man is evident, reducing him to a static position upon the land with a perishable or transferable stake easy of access to marauders and inculcating peaceful habits. Agriculturists are for these reasons averse to war and are forced into conflicts by the ruling grades of social organization, which dominate but are dependent upon agriculture. This preface is to bring out the comity between farmers, leading to the interchange of plants and seed, thus tending to the general diffusion of materials and methods. Farming from its nature could not be kept secret like some of the arts. The precious seeds of corn mythically given by the gods to the Zuni could not be long a tribal possession. The spreading of seed is a human urge.

Domestic Animals

The domestication of animals in its relation to agriculture appears to follow normal lines of growth of both industries. The coalescence of animal and crop husbandry was early and was preceded by phases where conditions were more favorable for grazing than tilling or *vice versa*. Both animal and plant domestication, apparently results of the application of the same principles, were in fact completed in the Neolithic in a region where the two progressed together, so that in the first glimpse of farming we find man dividing his efforts between flocks and crops.

Here and there is observed the ancient fission of the herder and farmer which obtains to this day. This is for the reason that the herbivorous animals require a wider range than the smaller animals which are in closer association with man. It is seen, however, that in the small farming of parts of Europe, probably typical of the Neolithic phase, and in many respects a survival, there is a division of labor producing the classes of herders named gooseherd, goatherd, cowherd and the like, acquainted with the habits of their respective charges.

[8] O. F. Cook, "Milpa Agriculture." Smithson. Report, 1919, pp. 307–326.

The domestication of the horse, an animal useful in the early times only as food, appears to have had an important bearing on the completeness of the taming of the large herbivores. This statement is based on the probable first economic use of the horse as a riding animal in rounding up cattle. In this accomplishment it must have been learned by daring spirits that a horse could be broken. The horse as a traction animal came late in agriculture in matter-of-fact lands where the age-long affection, almost worship, of the horse was not prevalent.

The economic results that came from the combination of tilling and rearing were of manifest importance. Industries not dreamed of in the preceding periods have extended to enormous proportions on the animal side of husbandry. It is not supposed that in the agriculture of centuries ago animals were recognized as consumers of crops produced by hand labor, yet there were no doubt seasonal crises when feeding was obligatory. It is seen that feeding grew slowly towards the present period when a large proportion of the crop is converted into meat.

This development has not been uniform in all countries or in the same degree. Chinese economics, for instance, had to choose between animal and human population. This brought about the practical elimination of the larger grain-consuming mammals and the substitution of the smaller mammals and fowls more or less self-supporting or feeding on offal. This feature is observed where agriculture entrenched on the larger areas required for grazing. It is probable that with the increase of population and consequent crowding in the United States and Canada history will repeat itself. There are symptoms now of a coming change in the diminishing consumption of red meat.

Conservation and Preparation of Food Supplies

Having sketched the chief phases of the development of agriculture, attention is now given to the outgrowth of an established system of tilling serving a constantly increased population. Storing, preparing and serving the food products of agriculture necessarily had their roots in a small way in the beginnings, even extending to the pre-agricultural phase. Whatever is acquired from the jungle or results from crops and fields has upon it the necessity of preparing it for future use in times of scarcity or between crops. This is the foundation of economy, the central motive in agriculture in contrast with the more or less mythical hand-to-mouth customs ascribed to inferior races.

Possession implies disposal. Each class of gathered food material requires its own process of preservation. The story of the preparation and storage of human aliment is so vast that only the salient points may be hinted at. As to animal food, the savage may be imagined as making his kill and placing the meat in contact with his digestive fluids as soon as possible without thought for the future.

A step forward and we have drying meat for preservation and later the employment of the first chemicals in smoke for more complete preservation. This satisfies the needs for a long period until the value of salt as an agent is discovered. Following on into later and modern periods it is seen that all the resources of the phenomenally advanced sciences are employed in the various conditions developed.

Vegetal food supply also presents many problems of preparation for preservation and storage. Root and tree crops exhibit methods of preparation by drying, the use of heat to alter toxic properties, as in breadfruit and cassava. The latter is put through the process of grating, pressing and baking to yield a storable product. Fruits are dried or worked over for putting away. Portions of edible plants are dried and stored by methods found suitable.

The introduction of cultivated grains into the dietary made for less prelim-

inary preparation of the crop and furnished less perishable materials for storage. The earth cache method appears early among the grain-raising peoples. Aside from bulk the grain pits of Ur of the Chaldees differ little from the cement elevators of the present, and both take their origin from the original and nearest available storage places in the earth.

There comes to view here the vast field of human endeavor in the agencies connected with the serving of food. The milling industry from the period when many farming operations were carried on by individuals shows at first the millstone and hand stone between which grain was broken for further processes. The primitive millstone accompanied the agriculture of grains over the world and in pre-agricultural times had its beginning use in crushing grass seeds and hard substances.

The mortar, ancient but not so primitive as the milling stones, also became an adjunct of the grain farmer. In the maize-raising area the mortar has a rather remarkable distribution. In the original home of maize milling was practised on the metate, an implement requiring workers to sit on the ground, a position, as has been stated, characteristic of primitive industry. On the spread of maize culture to other environments, especially to those of rain irrigation, the mortar appears. This is shown by the presence of a primitive metate in the semi-arid southwest on the boundaries of Mexican culture and the prevalence of the mortar in other parts of the United States.

The meaning of this distribution may be suggested by ancient and developed economy of the maize growers of the south which required fine flour and that of those who more recently acquired maize and practised ruder methods. In general the Indians of the rain-watered lands ate corn boiled as hominy or coarse mush bread for which the incomplete cracking in the mortar sufficed. Thin breads were unknown to the Indians north of the metate area. On the other hand, the standing posture of the mortar worker may indicate a preference for this working posture induced by the environment. While some consideration should be given to the presence or absence of mealing stones in some areas, a general view of the different habits in the larger areas does not give much weight to this suggestion.

In considering the mill for grinding grain it would appear that the concept of rotary motion with all its implication of tremendous future advantages was a development in a sense so unnatural or out of the line of animal motions that it came late in the achievement of culture. Thus the employment of rotary motion in the mill marks an important, almost radical, division between the culture history of the hand epoch and the epoch of machinery.

The mill appears in the naked, hard-grain areas of Europe in the Neolithic. Its use is not indicated in the rice area where the mortar alone is effective in hulling the seed. The western hemisphere, whose only grain was maize, developed no rotary mill.

Involved in the various lines of progress growing up with agriculture is noticed the effect of the means of serving food on the industry. Man generally has sensed the need of cooked food responding to his development as a creature, requiring that his food be assimilable. Nature furnished man with many forms of vegetal and animal foods edible without cooking, but not in many cases important as a basis of mass population.

With the agriculture of grains uneatable until put through various processes of preparation, it will be seen that several inventions are necessary. Incidentally, the parching of wild and early cultivated grains was probably the most ancient solution of the problem, continued among some tribes to the present along with boiling and baking of bread.

As with roots and other intractable foods, the pit oven was perpetuated in the roasting of maize. For boiling and other cooking processes pottery was necessary, and this art was contemporaneous with the permanent establishment of grain tillage. Pottery began along with farming in the Neolithic and its upgrowth solved problems at that time and continued with ever-increasing importance in later periods.

Military and Technical Organization

Beside the raising of crops and all the accompanying features of their preservation and disposal, the social and scientific by-products of an agricultural state are numerous and important. It is evident that a new problem of labor was uncovered and that it was quite different in amount and regularity from the sporadic, apparently unorganized work of the hunting or mixed preceding stages in which the family unit alone was to be supplied. The family supply in essence remains the fixed purpose of agriculture to the present, and this, as will be shown, has an important bearing on the regulation of agriculture on industrial models.

In the higher social organization at which agriculture as a general economic feature of life begins, it is seen that labor may be furnished by clans or other bodies associated by mutuality, such as relationship, religious ideas or predatory leadership or, as is general in clans under present observation, a combination of the first two. Theoretically and based on conditions observed in higher organized agricultural societies, some students considered labor as a commodity apart whose necessity was felt in the older social organizations.

That this is an error is shown in clan or communal labor. The Pueblo Indians produced a remarkable civilization without a labor problem in the sense of a separate body of enslaved or dominated workers. This is an example of a peaceful development in an isolated environment.

It appears that this state of affairs was quite wide-spread until there was superposed on agriculture directional orders of society exerting religious and military domination through rulers. This introduces the protection feature, many times necessary in itself but really based on the taxable values established on the land by farmers from which means could be drawn for aggrandizement of the ruling class.

It is argued that as agriculture demanded a fixed dwelling or sedentary life, there was frequently required in this stage a system of protection. In establishing this feature there were sowed the seeds of important human organizations developed in the social forms termed labor servitude, military and religious rule.

The organization of society growing at the top and diversifying its activities produced other orders of consumers based on agriculture thereby increasing the pressure on the land for the food supply. The labor problem kept pace with these developments and there came in the ancient nations devices such as the drafting of labor, slavery through conquest and the binding of labor to the land.

Nothing has been said as to the partition of the soil in agrarian communities. When land is held in common the rudiments of division also exist in the assumed rights of ranking families in the clan, the priesthood in assigning land, the strength in workers in families and other conditions which destined an ideal division. In general, under the clan system rights are acquired by former working of the land and announced intention of working the coming year. In case of failure to work the tract clan law throws the land open for use.

Development of Germane Arts

Agriculture as a basic industry on which stable and growing populations

must exist also aided in bringing about the most considerable advances in social life that may be noted in the progress of man. Some of these features having largely their origin in agriculture may be mentioned.

One of the earliest requirements of growers was a knowledge of times and seasons. These desiderata were undoubtedly acquired over a long course of observations on the heavenly bodies during the domestication of food grains. Out of this knowledge grew primitive astronomy, gradually showing a marked advance in applying crude mass metrics, developing into calendars. All ancient calendars had basically reference to agriculture.

The use of mathematical ideas expressing crude metrics of areas and amounts also evolved in agriculture and mark the unfolding of arithmetic and geometry. Engineering more clearly is a consistent outgrowth of agricultural operations. The earliest forms of this science are found in the selection of ground, clearing of growth involving primitive deforestation and timber work, grading, canal cutting, regulating water supply, and many other engineering jobs coming up in the exigencies of farming. Supplying also the labor to carry on the common and the outstanding engineering work of the world is not the least of the contributions of the farmer to the world's progress.

The participation of the farmer in the technique of commerce is observed to be small. In the early stages before the social complex began to take over the disposition of fruits of the farmers' labors as seen in the agricultural despotism of Egypt, Mesopotamia, China, Mexico and Peru, for example, there was nothing but folk commerce. At the best of the commerce of the ancient world there were inadequate facilities for the transport of appreciable amounts of foodstuffs to supply any considerable populations. There was also no real surplus, only a forced surplus whose export under despotic rule disregarded the needs of many.

The nature of man as a religious creature has caused the permeation of agriculture from the very beginning with lore, myth and observances to counteract the maleficent influences which render the art of tillage a game of chance. A glance at this vast field presented in Fraser's "Golden Bough" reveals the enormous penetration of religion in agriculture, its development there and its response to human needs of protection and guidance.

The above are some of the important features of civilization fostered under the stable conditions afforded by agriculture. It is, however, not supposed that these matters were brought to a state of enlarged usefulness by the farmer alone. The surrounding of the industry by religious sanctions and official controls furnished groups of men having assured subsistence and consequent leisure, who perfected them. The agricultural body with its preoccupation, its lore and crude laws of behavior remained in general ignorance. Agriculture has always been guided in all matters beyond the custom-honored technique of art.

State of Repressed and Dependent Population

When agriculture comes up into the view of history it is seen that society has extended to comprise a number of different orders from slave to king. Society growing from diverse efforts to produce coherence by rule has become in the classic examples a workable form. Division is on the line of intellectual and predatory employments on the one hand and manual employments on the other. The superstructure hides the primitive foundation.

The recognition of what are loosely called rights in common, realized to a great extent in ancient communal effort, was long in coming in more complex

society. The state of repressed populations up to the age of enlightenment was generally unfavorable. The beacon of education and the ability and means of making betterments were denied them. The farmer whose prime incentive was to support his family by the sweat of his brow remained generally in the low level which tradition and sanctions had assigned as his lot. In theory in Egypt the higher classes were "gentlemen farmers," even the Pharaoh being commanded by Ra to work the fields. Examples of organizing ability were no doubt frequent among the farmers in the theocratic government of the country, but farm labor was repressed. In 10,000 years and with all the various social forms developing, which may be called in the nature of experiments, the problem of the farmer has never been solved. In all the cataclysms that swept away the dominant and dependent classes the farmer stayed on. Mounds of earth are the gigantic cities of Mesopotamia and around them the farmers still work the soil with the tools and methods of the far ancients.

This represents the static condition of Asia. In Europe forces were growing that would lead to the emancipation of the farmer from the serfdom binding him to the soil. Here and there the voice of the repressed became heard and finally in Great Britain found that he was a unit of the state, exercised his crude power and secured certain rights. This was only a few hundred years ago, but the seed planted was destined to fruit in the wide lands of America and flourish in a way impossible in the narrow population-crowded lands of Europe. In America the farmer has never felt the repression of geographical and social conditions long the rule in Europe. Military, despotic, patriarchal and religious dominations did not enter into the American experiment. The turning-point of agriculture was in England, but the realization of its possibilities was in America.

Appearance of Surplus

The preparation of crops for market was an almost unknown factor in early agriculture. The germs, however, existed in the beginning stages when some sort of sporadic exchange was carried on. It is seen that the economic question of a surplus did not come up in early agriculture. The ratio between population and food supply remained fairly constant. The population also beyond that engaged in farming was small and industrial concentration in manufacturing was scarcely in existence, the units on the land being self-sustaining in all respects, as in the former days of domestic and individual arts.

The history of agriculture shows clearly that the quite recent tendency has been through improved appliances and methods to foster an increased and dependable surplus beyond the capacity of the population to absorb. The story brings out the succession of the digging stick, the hoe, the plow, the mower, reaper, tractor combination, together with fertilization, improvement of grains, methods of rotation, intensive cultivation on the land, and the use of fire, the ax, the drag, harrow, etc., all contributing to a total surplus. Incidentally, also, these in the improved state bring about the feeding of increasing population and an inevitable surplus. It will be seen that the major items of this development derive from agencies outside agriculture due to the acceleration of what some genius of characterization called economic man.

The object of modern agriculture is a surplus of production. Upon this, as has been suggested, is based civilization and its organizations and industries generally. But the surplus may be looked upon as a result of scientific and mechanical aids coupled with abundant acreage for expansion such as was furnished by the discovery of the New World and extensions of populations in eastern Europe and Asia.

It may be asserted that the first appearance of a surplus that could be handled on commodity terms was in America. It was not the storage of full years in anticipation of lean years, but part and parcel of the vast complex of modern civilization which has means of penetrating to the furthermost corners of the earth carrying finished and raw materials.

Development of Industrial Organization of Agriculture

The development of the modern industrial organization of agriculture as suggested is part of a long chain of gradually unfolding events. It is evident that agriculture is breaking out of the shell which has bound it for several thousand years. The long course of advance shows that agriculture was first merely a family or group asset, then successively a local asset, national asset and finally an international asset.

The latter stage, the outgrowth of a complex of material expansions in which transportation takes a prominent place, presents obvious benefits to mankind. Intercommunication, which is aiding in the effort to establish a central board of information on crop probabilities and the existence of or lack of surplus in various countries, is destined eventually to help the farmer. Famine, which perennially dislocated the affairs of nations by the concentration of human misery, passes over the nations who are in touch with the new age.

Tendency to Overproduction

While a surplus is commendable as showing the difference between good farming and poor farming, overproduction may be regarded as a failure in another direction. The tendency of modern skilled and aided farming is overproduction. All the myriad efforts of science and promotion are bent on production of a surplus, meaning overproduction, which when not fitted to population demands is a clog on economic adjustment. Cheap labor and poor farming is counterbalanced by improved machinery and scientific farming, and the result is overproduction. What should seem desirable is the reverse, for it hits back finally to the unit, stable from the beginning, that is, the family.

The contributions of science to agriculture are numerous and important. For the first time in history has the subject been examined in a methodical manner and correlated with most of the branches of science. That overproduction is perhaps one of the results is not to the disparagement of science; problems like this are in the field of science applied to government policy.

Some of the fundamental contributions of science are insect and disease control, increase of practical knowledge in animal husbandry, soil analysis and scientific fertilization offsetting the "mining" of soil, and other important items. Yet to come may be predicted the extension of the regulated increase in plant and animal variation and weather prediction by the variation of solar radiation. It must be considered also that at the present rate at which chemical science is growing, the food supply may be put on a new basis defying former prediction of overpopulation and famine. Chemical advances point to the lines of utilization of raw materials for the manufacture of food. If accomplished as anticipated, there would be a revolution of the business of farming.

In view of modern discoveries of the essential rôle played by vitamins in the metabolism of foods, it is likely that new deductions may be made on the decay of nations, using as a basis the presence or absence of these substances in the diets which they have preferred or that nature has forced upon them. Probably in the future the advance of chemical sci-

ence will reduce the present apparent necessity of raising enormous crops of small vitamin content. This would allow the farmer to concentrate on limited, more valuable crops, saving labor and giving him more leisure. It is possible that in the review of the development of agriculture coupled as it is with the development of mankind some ideas may be found of use in the present search for aid to the farmer.

Agriculture became a business by the agencies of general progress before the world recognized that there had grown up an industry cognate with the great mechanical industries. Mechanical industries, of course, grew up against the background of farming. This phenomenon was long unperceived, and only recently have men familiar with social changes begun to attempt its regulation.

Stimulative and Corrective Agencies

There is no intention to propose remedies here or to do more than to suggest lines of approach to the subject. There is in the United States at least talent to select the crucial ideas and ability to find the means to carry out reforms in agriculture. Vastness should be no bar to organizations of relief measures, but custom and tradition are.

The psychology of the farmer is the outgrowth of millenniums of struggle, and on account of it he may be described as showing traces of the individualistic and static life he has led in the past. This life we now see as disturbed by the infinitude of currents of modern progress, singling out especially education.

Dissatisfaction is not now with the inadequate returns and opportunities, as under more or less severe despotisms in ancient Egypt and Mesopotamia, but in the complex economic conditions that to-day seem to leave the farmer out of the picture. To line the farmer up with these conditions there are suggestions of organization in great units which have been carried out in areas never taken up by the small farmer.

The difficulty of this project is its application in areas covered by small farms on which the time-honored independence of action is practised. In it also are seen the return to the communal and feudal systems highly difficult as a project even under the copartnership in government of the present time. In any attempt of this sort the small farm unit must be satisfied to enter the scheme as an employee of the industry. Perhaps this eventually will become practicable.

This scheme would require a census of farm products in demand and the supply in order to get a proper correlation. This infers a control of acreage put in crops, which so far no one sees as workable. It also suggests a concentration of effort on the best land for certain crops, thus getting the diversity of required products on the best locales, throwing unuseful land into forests, etc. It is likely that in the future farming may be concentrated on the products of vitamin efficient foods, thus reducing substantially the burdens of needless production.

It will be seen that the matters advanced here look forward to a more rosy future, but the immediate practical aid awaits the earnest efforts of enlightened statecraft.

WHAT IS EVOLUTION?

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It has been said that the history of the world is the history of ideas. Like controlling forces in the ancient world were the Greek ideas of fate, justice, courage, beauty and the *Logos* idea. Similarly, in the middle ages the ideas of obedience, faith and love were influential in determining not merely the institutions of the church and the daily life of the people, but the course of history itself. In our own Anglo-Saxon world we may find illustrations in such ideas as liberty, equality, opportunity, efficiency and democracy.

In the nineteenth century the idea of *evolution* first took definite form, and its influence in the thought of that time and in the first decades of the present century was unbounded. Evolution has given us a new conception of the world, startling in its comprehensiveness, applying to animal species, to terrestrial and celestial changes, to language, to human institutions, even to the mind and to our moral laws. It has given us a new method, the genetic method, revolutionizing our ways of approach to science. It has added new charm to the study of plants and animals and a new wonder to the study of the human body.

Incidentally the evolution idea of the nineteenth century affected human thought and institutions in another way. It came into conflict with the church in respect to the origin of man. Violent controversies arose in the last centuries respecting the origin of man and the origin of mind and morals as a result of the introduction of the evolution idea; and in the most recent years these controversies have broken out afresh, disturbing the progress of science and introducing bitterness into the councils of religion.

Hence we see the importance of understanding just what evolution is. A critical analysis of any of the great, influential ideas of history would be useful. Particularly timely is an analysis of the idea of evolution. In the following discussion the primary aim will be to find out what evolution means. It is still too early in the history of the twentieth century to attempt any final analysis of this concept. In this paper I shall undertake to trace through the various evolutionary philosophies of the nineteenth century and of the first quarter of the present century, with a brief preliminary review of such philosophies in ancient Greece and in modern times previous to the nineteenth century, with a view of finding out what the various writers and scientists have meant by the word evolution.

Evolution is an idea belonging not to any one time, but to all the ages. On the other hand, evolution is often spoken of as belonging only to the last century because it received its greatest development in that period and because it was then first used as a basis for science and philosophy. Great advances were made in science as a result of the evolutionary hypothesis, and philosophical systems were built up around the concept. At the close of the nineteenth century the evolutionary philosophy was triumphant; it was the last word in science and philosophy. No man of genius doubted it. How could he when proofs offered in support of it seemed so logical and self-evident? The concept evolution was *the* scientific hypothesis. It spread rapidly from one science to another until it was the primary method of all the sciences, and was applied to every field of thought. Evolution reigned supreme as a theory, and peo-

ple had so much respect for it that they almost made a god of it. Every explanation of social, religious, inorganic and especially organic phenomena was in terms of this hypothesis, this fact being largely due to the monumental work of Darwin and his contemporaries. Up to the time of the great World War this was the general attitude toward the evolutionary philosophy, but during the post-war period there has been a decided reaction against it. In less critical circles this has taken the form of a violent reaction to which we refer as fundamentalism. In philosophical and scientific circles it has taken the form of a careful inquiry into the causes, manner and meaning of evolution. It is true of most scientific theories that some revision of them is necessary from time to time, especially when they are so vitally connected with so many fields of thought as evolution is.

Libraries have been written about this concept, partly because it has been a source of irritation to religion, but mainly because it is a fundamental hypothesis of science. Many definitions have been formulated, around which whole systems of philosophy have been built. There is a vast amount of literature explaining evolution, offering arguments in support of it and applying it to the various sciences as a method. Again, much has been written attacking the theory—setting forth arguments to disprove it. But, as we search further, we find that very little has been written concerning the concept itself.

Before considering an analysis of the term evolution, it would be well to have in mind the etymology and meaning of the term itself. Evolution comes from the Latin *evolutio,* an unrolling; *e,* out, and *volvere,* to roll, *evolvere* meaning to unfold, unroll, to open and extend, to disentangle. Is this what the various theories and definitions of evolution mean?

The first reference to anything like evolution comes from the Ionian school. Thales, the first of this group, theorized about the origin of all things and named water as the substance from which all things come. Anaximander said that it was not water, but the infinite, an eternal, imperishable substance out of which all things are made and to which all things return. Anaximenes tried to define the substance, which Anaximander described, by calling it air. Thus the only contribution which the Ionians made was the idea that all things come from one substance by some process, but they did not have any notion as to the nature of this process.

Heraclitus was the great exponent of the philosophy of change. He believed that all things are in constant motion, nothing is fixed or static, everything is in a state of ceaseless change. "You can not step twice in the same river, for other and yet other waters are ever flowing on." It was through this philosophy of change that the notion of evolution received its most striking statement at the hands of Heraclitus, "who regarded all nature as a scene of 'becoming' according to a certain law of proportionate exchange termed by him *logos.*" He did not have any notion of the transformation process of life or of the evolution of species, but he conceived nature, in his broad view, as involved in ceaseless change, and yet always constituting a uniform whole. The contribution which Heraclitus made to evolution is important because he was the first to introduce this concept of perpetual change. Parmenides, who stoutly opposed the philosophy of change, believed that reality is eternal and immutable, and that all change is inconceivable. Parmenides' opposition is significant because it led his successors to propose an explanation for apparent change. This introduces us to the important hypothesis by which change is explained as due

to the recombination of a certain number of fixed and so-called "elementary" substances, namely, four in the case of Empedocles, an infinite or indefinite number of "atoms" in the case of Democritus, about ninety elements in the case of modern science and an indefinite number of electrons or centers of electrical energy in the case of recent physics.

Empedocles has justly been called the father of the evolution idea because he took a great stride in advance of his predecessors. He believed that there were four elements, earth, air, fire and water, which were acted upon by two mythical forces or beings, love and hate—attraction and repulsion. These two forces always act together upon the four underived, unchangeable and indestructible elements, arranging and rearranging them into different combinations by means of a process of endless change. He explained organic evolution as the triumph of love over hate.

We have space only to mention five sparks of truth which may be found in Empedocles' philosophy: first, that change is explained as a recombination of a number of fixed elements; second, that the development of life was a gradual process; third, that plants were evolved before animals; fourth, that imperfect forms were gradually replaced by perfect forms; fifth, that the natural cause of the production of perfect forms was the extinction of the imperfect.[1] Also in his explanation of organic life he made a vague prophecy of the survival of the fittest and of natural selection; but we do not find that he had a well-defined idea of evolution.

Aristotle literally ushers us into a new world of thought, because he towered high above his predecessors and made a lasting impression upon the world by the force of his genius, demonstrating to us the surprising grasp which he had of the whole situation. There are two reasons why we should pause and consider Aristotle, and which make him important in a consideration of the evolution idea. First, his concept of biological evolution. He believed that both the plant and animal kingdoms are graded from simple to complex—imperfect to more perfect—as a result of form being realized in matter. Second, his philosophy of evolution. Aristotle had a philosophy of evolution, which fact we do not find in Darwin, who did not have a world view of cosmic evolution, but simply a theory of the origin of species. This, then, makes Aristotle important, because he had one theory by which he explained all things. Later we shall find that there have been others who have propounded theories of general evolution, such as Spencer, LeConte, Bergson, Morgan and others; but Aristotle was the first and most important.

Aristotle rejected the ideas of both Democritus, who reduced all things to moving, material atoms, and Plato, who assumed ideas separate from matter, and took a middle course, assuming that both matter and form are real. He held that matter had potentiality and form actuality, and that matter realized itself or became actual in form. Form and matter are inseparable; there is no matter without form, and pure form—that which has no matter—is the Prime Mover or God. Thus, for him, development was a gradual, continuous, unitary process in which matter, the potential, realized itself in form, the actual. When applying this idea to nature, he said that there is a complete graduation, and that nature proceeds constantly by gradual transitions from that which is imperfect to that which is perfect, in other words, he believed in the unity of causation in nature. Thus at the very core of his evolution idea was this "internal perfecting tendency," which drives the organism progressively onward to more perfect forms with man as the final product. It is this process

[1] H. F. Osborn, "From the Greeks to Darwin," p. 141.

of realization which we shall find very significant when we come to a consideration of the evolutionary philosophies of the twentieth century.

Lucretius, in his "De Rerum Natura," did not make a great contribution to the philosophy of evolution because he merely summed up the pre-Aristotelian philosophy. Although very mechanistic, it is important in the case of Lucretius to notice what appears to be an almost inadvertent subversion of his boastful mechanistic philosophy by the introduction of an element of spontaneity in the atoms, which he naïvely likens to free will in man.

The first great contributor to the philosophy of evolution after Aristotle was Augustine. Although Augustine was a churchman, he was greatly influenced by the teachings of Aristotle, which he harmonized with his Christian theology, and thus gave us a new concept of development. Putting it in modern terms: "In the beginning God made" the first single cell—germ or seed—in which all things that are found in the world to-day were implicit, and by a process, governed by natural laws with which the Creator endowed this first piece of matter, have become and are becoming explicit. The first cell was the potential universe with all things that are found therein. In this concept we find a trace of Aristotle's forms, and matter realizing itself in a successive series of forms, and the materialistic philosophy of the Greeks, also the Christian concept of the Creator who endowed matter with these natural laws.

There are two things of importance in Augustine's philosophy of evolution with which we should be impressed. First, his idea of an orderly development in the world. This is rather startling, when we remember that it came from a church father, because the church taught "special creation." Augustine, however, conceived the universe as coming from the first seed or germ in an orderly manner, just as the oak grows, "in that order with which we are familiar in nature," from its humble beginning in the acorn to the mighty giant of the forest. Second, and the most important, his notion of the potentiality of the germ. Here we should pause a moment, because Augustine has introduced into the evolution idea a new thought—the potentiality of the germ. Nowhere among the Greeks did we find this idea expressed—the entire universe being implicit in the first germ. This is truly evolution. Augustine thought that development is an unrolling, an unfolding of that which is in the germ, the implicit becoming explicit, and this is the true meaning of the term. Thus Augustine was the *first* to have a concept of evolution which the term clearly and adequately expresses.

The contribution which Thomas Aquinas made to the concept is essentially a reinterpretation of Augustine's idea. He interpreted Augustine as saying: all the potentialities were not given by the Creator in the beginning, but at different times. In the beginning God gave matter a certain potentiality which gradually became actual, later. He added another potentiality which by a gradual process became actual, then He added another and another and so on. At one time matter "received power to produce" grass and trees, and at another time to produce animal life. Development, then, according to Aquinas seems to be an epigenetic process—a gradual building-up of potentialities which were added at different times.

With the advent of the seventeenth century there was a great awakening in science which led to much speculation concerning evolution. There was a whole host of writers who contributed to the evolution idea, the naturalists—Linnaeus, Buffon, Erasmus Darwin; the speculative evolutionists—Millet, Diderot, Oken; the natural philosophers—Bacon, Descartes, Leibnitz, Kant, Schelling, etc., all of whom we must pass over

because we do not find in their writings any definite concept of evolution.

Lamarck's contribution to evolution, made essentially to biological evolution, may be found in the statement of his four laws. In the first law he assumes internal forces—life which was inherent in the first created forms—which are at the basis of all growth and development. The second law, which deals with the "needs" or "wants" of life, as he termed them, is the law which was most severely criticized and misunderstood by his contemporaries. They interpreted his law as meaning that an animal could acquire any organ by simply desiring it. This could not have been farther from the truth. His conception was: a new situation is presented to an organism, the organism must needs react to this changed environment by the use of different organs and parts from those it was in the habit of using, and probably cease to use the organs which it had used in the past. Thus he did not mean mental desires but the satisfaction of physiological wants or "needs." The third law, the law of use and disuse, is the basis for the second law, for if an organ or part is used it tends to develop and become strong, but if it is not exercised it becomes weak and will disappear. The fourth law, which maintains that an organ, organization or function once acquired by an organism is preserved by generation, raises the question of the inheritance of acquired characters. We are all, of course, familiar with Lamarck's classical example of the giraffe and the way in which he supposed it acquired its long neck.

Upon these four laws rests Lamarck's whole concept of evolution. He starts with the assumption: given certain vital, internal forces which cause growth, then, the living, growing organism adapts itself to its environment because of certain needs or desires; these adaptations persist through use or are lost by disuse; and finally, the acquired adaptation or organization is transmitted to new individuals. If his assumptions and these laws are true, and acquired characters are inherited, then the problem of evolution becomes much simpler.

Let us look a little more closely into the meaning of Lamarck's laws and ask first: What did he mean by growth? According to the first law, it is simply the function of internal forces which "increase the volume of every body that possesses it, as well as . . . the size of all the parts of the body up to a limit which it brings about." Thus it is not an unfolding process in which the implicit becomes explicit, as Augustine taught, nor the "perfecting tendency" of Aristotle. He uses growth in the sense of coming to maturity. But growth alone does not account for new species. "Internal forces"—what are these? They are the natural forces of life with which matter is endowed by its Author. He did not analyze these forces; he simply assumed them.

If growth alone does not account for new organs or new species, how, then, do new organs and new species arise? A certain part becomes gradually specialized in performing a certain function; growth causes the part to grow—become larger; use strengthens it, and thus a new organ is gradually formed. This acquired character is transmitted to the next generation, other modifications are passed on by inheritance, some characters being acquired and others lost until the very organization of the species is so changed that it has become a new species. Thus, in the last analysis, his evolution idea depends upon the inheritance of acquired characters and "internal forces" which he did not analyze. It is just these "internal forces" that we would like to know more about.

Between the time of Lamarck and that of Darwin, the evolution idea fell into disrepute because of the strong opposi-

tion against it. There are, however, two names which we must mention, which belong to this period, because of their influence upon Darwin's thinking. These men are, Lyell and his "Principles of Geology," and Malthus with his work "On Population."

Darwin put forth his ideas concerning evolution in his monumental work, "Origin of Species." It is not necessary to review, for the intelligent reader, the details of Darwinism, but a mere mention of its assumptions is sufficient. Darwin made the following assumptions: the extreme fecundity of nature, struggle for existence, variation, heredity and natural selection.

Let us turn to a consideration of these assumptions. The first one is certainly true, nature is extremely prolific. It has been estimated that from a single pair of robins, if none die except from old age, there would be at the end of ten years over two million individuals. Next we come to "struggle for existence." Why is there a struggle for existence? Why do not plants and animals succumb to the adverse conditions of their environment instead of maintaining a struggle? When the great ice sheets came down from the north, they crowded practically the entire plant and animal population of the entire North American continent into a comparatively small area—the southern half of the United States. Certainly crowded conditions existed; competition must have been keen; there must have been a struggle for existence. The question is: was the struggle for existence due to the crowded conditions and the resulting lack of food, or was it due to some other reason? Certainly there must be some internal force or drive which forces plants and animals to do the utmost to preserve their integrity. But why do animals struggle? Is it to satisfy hunger? But why do they seek to satisfy hunger? The reply is that they seek to satisfy the biological needs of their organisms. To satisfy these needs is the very nature of life itself, and it is just here that we unfold the secret. There is a struggle for existence because of the insurgency, activity and spontaneity of life. This being true, the Darwinian idea of struggle for existence is of little interest to use because behind it is the will to live which is life itself.

Darwin merely assumed variation and heredity and did not try to justify or explain these assumptions. He insisted upon the idea that all minute variations, which we to-day know are to a great extent non-heritable, were the principal materials for natural selection to work upon. He believed that all variations are heritable. These chance variations, he thought, occur in all directions and in all structures in a haphazard manner, and only the useful are selected and preserved. Here is the difficulty. How is the first, almost imperceptible variation in a favorable direction of selective value, so as to effect the survival of the individual? What would be the value of the first few hairs of a mammal, that this variation should be of selective value? When we think of some of the complex instincts and adaptations which we find in organisms, we are led to doubt the probability of their arising from slight variations, selected and preserved by natural selection.

Now that we have examined Darwinism and have considered some of the objections to it, we may ask two questions: Is Darwinism, in the truest sense of the term, evolution? Did Darwin have a philosophy of evolution? In one sense we must answer the first question in the negative, in another in the positive. We do not find in Darwin's idea, as we did in Augustine's, any suggestion of an unrolling or unfolding process—that which is implicit becoming explicit. The variation-selection idea certainly does not suggest an unfolding, but rather

a building-up process. Evolution taken in this sense can not be applied to Darwinism. But there is another aspect to the question. If by evolution we mean biological development, the development of all plant and animal species from some common stuff by some process, then Darwinism may be called evolution. Natural selection is a mechanism by which the origin of species may be explained. If there is a struggle for existence due to the very nature of life, if slight chance variations occur which are purely fortuitous and if the forces of heredity are assumed, then it is possible to explain all the complex adaptations of structure and of function in organisms, instinct, intelligence—all by means of natural selection. As to the second question, we are somewhat disappointed. Darwin dealt entirely with the origin of species, and did remarkably well, but he did not expand his theories to include the origin of the universe and all things contained therein. It is in this sense that we must say he did not have a philosophy of evolution. Thus we see that Darwin's concept was not one of unfolding, but one of upbuilding.

While Darwinism is fresh in our mind we must briefly consider Neo-Darwinism. Weismann in his theory of germinal-selection transferred the struggle for existence and selection of Darwin to the germ plasm. He thus gave selection great prominence, but failed to see the great difficulty—the impossibility of verification. Germinal selection is entirely theoretical and can not be subjected to experimentation and verification. Although Weismann did not make any great contribution to the concept of evolution, we must say that he made a sincere attempt to explain the origin of all plant and animal species by a single process.

Another modification of Darwinism may be found in the various orthogenetic theories. Orthogenesis adds to the concept of evolution the idea of direction in evolution. Evolution is not an indefinite, haphazard process, but it is a process by which nature is getting somewhere. Variations occur, but they occur in a linear direction because of what the previous variations have been. If this is true, and evolution is progressing in a definite direction, then it seems almost inevitable to assume a director or guiding force. We can not enter into further discussion of this point here, but will refer to it again later. Let us bear in mind, in passing from orthogenesis, that it is a new idea added to the concept of evolution.

We must turn back in our thought to the time of Darwin, and consider Herbert Spencer, for undoubtedly the reader has been anxiously looking forward to a discussion of his famous formula. Lamarck and Darwin, we found, dealt entirely with biological evolution, but Spencer presented a philosophy of evolution. It is for this reason that we are interested in his famous formula.

Spencer's final statement of his formula stands thus: "Evolution is an integration of matter and concomitant dissipation of motion; during which the matter passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity; and during which the retained motion undergoes a parallel transformation." This formula he applied to all phenomena, inorganic, organic and superorganic. Its scope is broad, and nothing escapes it. It is applicable to all things, and thus gives unity to all phenomena.

Whether it be in the development of the earth, in the development of life upon its surface, in the development of society, of government, of manufacture, of commerce, of language, literature, science, art, the same evolution of the simple into the complex, through successive differentiations, holds throughout. From the earliest traceable cosmical changes

down to the latest results of civilization, we shall find that the transformation of the homogeneous into the heterogeneous is that in which progress essentially consists.[2]

Evolution, for Spencer, was a process of change—a process of integration and differentiation. The elements or materials of this evolutionary process—matter, motion and force—are not ultimate; they are modes of the unknowable, as Spencer calls them. The unknowable is the power, cause or source which is behind and responsible for the evolutionary process. What it is we do not know; but that it is, we are certain. Concerning matter, motion and force—the knowable—Spencer says that matter is derived from motion, motion from force and force from the unknowable. What is the unknowable? I don't know. Thus we are led to agnosticism. Is, then, Spencer's formula hopeless; has it nothing of value to offer us? Let us see.

Whether in Spencer's mind the formula passed for an explanation of the development of all things is difficult to say; but with many of his followers we do know that it passed for a final and perfect explanation. But, does it explain anything? We can hardly say that it does. Spencer uses the terms, integration, concomitant dissipation, indefinite, incoherent homogeneity, etc., very glibly, and the careless thinker might be led to mistake a pleasing statement for an explanation. To say that evolution is the integration of matter and the dissipation of motion does not explain it, but merely states a possible fact. It does not state what causes integration, how matter is integrated or why integration of matter is accompanied by the dissipation of motion. Even if this statement is true, and during the integration of matter and concomitant dissipation of motion, matter does pass from an indefinite incoherent homogeneity to a definite, coherent heterogeneity, what of it? To say that the development of a tadpole into a frog is an integration of matter and concomitant dissipation of motion, during which the tadpole passes from an indefinite, incoherent homogeneity to a definite, coherent heterogeneity—the frog—does not explain the metamorphosis. It may be true, but we are little wiser than we were before.

[2] Morgan, "Spencer's Philosophy of Science."

The reader may object to this criticism on the ground that the purpose of science is not to explain but to describe. But is Spencer's formula a valid description of evolution? No scientist to-day would answer this question in the affirmative without qualification.

Spencer explained the world as a redistribution of the modes of the unknowable—matter, motion and force—but as soon as we inquire more deeply into this mysterious trio we are referred to the unknowable; and instead of obtaining an explanation we are brought face to face with agnosticism. This form of agnosticism does not appeal to the modern student of philosophy, and hence Spencer's philosophy has lost ground. It is rather disappointing, after studying Spencer, to say that his philosophy does not throw much light upon the concept of evolution. But is there nothing which we have gained from Spencer? Certainly! He contributed two important ideas: first, that evolution is a single total process by means of which we can account for all things; and second, his idea of the unknowable as the force, source or power which is behind the whole process. We shall hear more of these two ideas when we consider more recent philosophies of evolution.

Another definition of evolution which interests us is LeConte's, which we find in his book entitled, "Evolution: Its Nature, Its Evidences, and Its Relation to Religious Thought" (1887). The statement of LeConte's definition is as follows: "Evolution is (1) *continuous progressive change*, (2) *according to*

certain laws (3) and by means of *resident forces.*" LeConte, like Spencer, emphasizes the fact that evolution is a universal process, but he confines his discussion almost entirely to biological development.

What is "continuous progressive change?" LeConte does not give us a satisfactory answer to this question. He tries to describe change by saying that it is like the stages in the individual—germ, egg, embryo, infant and maturity. This is true but it does not tell us what change is. He tries to explain a dynamic concept in static terms. What *progressive* change is, is even less clear. Possibly, what he meant was: evolution is a process of change, each change being an improvement in adaptation to the environment, and resulting in an increase of complexity.

LeConte says that development is according to certain laws. What are these laws? His first law is the law of differentiation—increasing complexity and specialization. His second law is the progress of the whole. What this "whole" is, he does not make clear; but whatever it is it seems to progress in the direction of increasing complexity. Since this seems to be its chief characteristic, the second law does not add anything to the definition, but merely restates the first part of it. The third law is the law of cyclical movement—an unimportant and practically negligible law, as he himself admits. We have left, after this partial sifting of this definition, change, differentiation and "resident forces." This latter element we shall now consider.

LeConte's "resident forces" are *natural* forces and therefore resident or inherent, as all natural forces are inherent. They are God, divine will, or vital force imminent in nature. Thus LeConte assumes God as the resident force which is in nature and which is responsible for the process of change and differentiation. But how this change and differentiation comes about he does not make clear to us.

Let us sum up this definition as we have interpreted it. Evolution is change and differentiation in the direction of greater complexity, by means of a vital force. This is apparently all that we have left that is meaningful. There is nothing expressed in this definition which has not been expressed before; it merely brings some of these thoughts together to form one concept. Change, we have found, goes back as far as Heraclitus; the idea of complexity we found in Lamarck, Darwin and the Neo-Darwinians; differentiation we found in Spencer; and the vital force or God is the Christian concept. Thus as we turn from a consideration of LeConte's definition to creative evolution, let us bear in mind that he summed up some of the ideas concerning evolution which came before his time.

Bergson's philosophy claims to transcend both mechanism and radical finalism, although it does partake of the second to a certain extent. His philosophy regards the world as an organized whole. The harmony, however, is far from perfect; it admits much discord, because each species, each individual even, retains only a certain impetus from the universal vital impulsion. Life, then, is the continuation of one and the same impetus, which is divided into divergent lines of evolution, each line preserving some of the essential causes working along it, and this common psychological element accounting for the fact that we find similar effects at the ends of two different lines of evolution.

He examines the current theories of evolution and maintains that none of them is sufficient to account for the facts. Each represents an aspect of the process, and thus is only partially true; they are only partial views of a reality which transcends them all. Bergson finds in evolution an original impetus of life, passing from one generation to the

next through the developed organisms which bridge the intervals between the generations. This original impetus, Bergson thinks, is sufficient to account for the facts and process of evolution.

Bergson makes his idea of the original impetus clear by the use of a number of illustrations. A vertebrate eye, he contends, should not be thought of as a sum of many parts, but as having a single process or activity—vision. The movement of an arm from point *A* to *B* should not be thought of as an indefinite series of positions, but as a single unitary process. Again, he thinks of the process of development as a subterranean stream which is forcing its way through rock and sand, and whose course is being determined by that which it encounters as well as by the force which it maintains. Or again, he thinks of this process as a rocket flying through space and bursting.

This, in essence, is creative evolution: "Consciousness, or supraconsciousness, is the name for the rocket whose extinguished fragments fall back as matter; consciousness, again, is the name for that which subsists of the rocket itself, passing through the fragments and lighting them up into organisms." A vital impetus passing through matter—the inverse force—and the interplay of these two forces, or the unrolling of this conflict, is evolution. Evolution is not a building-up process because the parts are complete and finished, neither is it progressing according to a plan, else it would be created already. It is a unitary process, simple and indivisible, an action and not states. From this point of view

> life appears in its entirety as an immense wave which, starting from a center, spreads outwards, and which on almost the whole of its circumference is stopped and converted into oscillation; at one single point the obstacle has been forced, the impulsion has passed freely. It is this freedom that the human form registers. . . . As the smallest grain of dust is bound up with our entire solar system, drawn along with it in that undivided movement of descent which is materiality itself, so all organized beings, from the humblest to the highest, from the first origins of life to the time in which we are, and in all places as in all times, do but evidence a single impulsion, the inverse of the movement of matter, and in itself indivisible. All the living hold together, and all yield to the same tremendous push.

In passing from the nineteenth century to the twentieth and to creative evolution, the reader has undoubtedly been struck by the marked differences between the evolutionary ideas and philosophies of the nineteenth century and creative evolution, which we have just considered. The earlier philosophies, with the exception of Spencer, dealt largely with biological evolution and the origin of species—the products of evolution. Bergson is not concerned so much about the origin of species; for him evolution is a process, a creative act, not states or products of evolution, but the process of becoming. He criticizes earlier evolutionists for thinking only in terms of states and not in terms of action. Creative evolution is simple and readily understood when compared to a rocket which is given an initial push, and which push persists throughout the entire movement. The movement is one and indivisible, its unity being essential; it is a single act—a single impulsion resisting matter. The rocket bursts and the sparks fly in different directions representing the divergent lines of evolution; but all is due to the single initial and limited push which makes the entire movement a single act.

Thus as we pass from Bergson's creative evolution to Morgan's emergent evolution let us bear in mind these points: evolution is a unity—a single movement—and an unrolling of the conflict between the original or vital impetus which is realizing itself in matter, and matter which is the inverse action. When we thus understand evolution, we see the forest and not the trees which our intellect insists upon examining.

Morgan says that evolution is the name we give to the "comprehensive plan of sequence in all natural events." Emergent evolution, then, lays stress on the "incoming of the new." The advent of life, the advent of mind and the advent of reflective thought are salient examples of this "incoming of the new"—emergence. The instances of emergence are beyond the ability of man to number, for in the physical world the advent of every new kind of atom and of each new kind of molecule is an example of emergence. This new molecule is more than a rearrangement of preexisting part—it is something new. The characteristics and qualities of the substances from which it was formed are one, but those of the new molecule are another, and vastly different from those of the elements. It is something absolutely new—a new "form of relatedness."

In brief, emergent evolution may be summed up, in part at least, by quoting the following extracts. Diagrammatically emergent evolution is represented by a pyramid.

> Near its base is a swarm of atoms with a relational structure and the quality we may call atomicity. Above this level, atoms combine to form new units, the distinguishing quality of which is molecularity; higher up, on one line of advance, are, let us say, crystals wherein atoms and molecules are grouped in new relations of which the expression is crystalline form; on another line of advance are organisms with a different kind of natural relation which gives the quality of vitality; yet higher, a new kind of natural relatedness supervenes and to its expression the word "mentality" may, under safeguard from journalistic abuse, be applied.[3]

As a part of his constructive philosophy Morgan takes under acknowledgment three things:

> First, we acknowledge a system of physical events, intrinsically existent, as that which is basally involved in our complete scheme. Secondly, we acknowledge God as the ultimate Source on which emergent evolution is ultimately dependent. . . . Thirdly, we also acknowledge unrestricted correlation of the kind Spinoza postulated under his doctrine of attributes. . . . It is within such an acknowledged frame of reference, with its three-fold relatedness of involution, dependence, and correlation, that world-events take their course "in space and time." But dependence on God is *sub specie aeternitatis*.[4]

In emergent evolution each new emergent is a new form of relatedness supervenient upon the lower levels, involving the lower level, but the lower level is in turn dependent upon the higher. Evolution is a unitary process passing from base to apex of the pyramid—from space-time to deity—the Nisus of which or activity is God.

With this presentation of emergent evolution it is almost needless to reiterate the salient points of the concept; but for the sake of clearness let us restate them briefly. First, we find the idea of change or progress emphasized—a progress from lower to higher levels. But the new is not a rearrangement or mixture of that which previously existed; it is something new with new qualities and characteristics—an emergent. The emergent is a new form of relatedness supervenient on the lower levels. Thus the whole process is one, because the emergent involves the lower levels, and the lower levels are dependent upon the new emergent. The whole process from base to apex is psychical, and thus similar in some respects to Bergson's creative evolution. It is difficult to criticize Morgan's constructive philosophy because he avowedly takes upon acknowledgment the physical world and the Nisus or God through whose activity emergents emerge.

> For better or worse, while I hold that the proper attitude of naturalism is strictly agnostic, therewith I, for one, can not rest content. For better or worse, I acknowledge God as the Nisus through whose activity emergents emerge, and the whole course of emergent evolution is directed. Such is my philosophic creed, supplementary to my scientific policy of interpretation.[5]

[3] Morgan, "Emergent Evolution," p. 35.

[4] *Loc. cit.*, p. 116.

[5] *Loc. cit.*, p. 36.

The last of our twentieth century concepts is found in Patten's "The Grand Strategy of Evolution." Patten believes that evolution is a continuous creative process passing from infinite chaos to infinite perfection, and that "mutual service is the great creative, disciplinary, and saving force of nature. It tends to give community and harmony of action to her constituents, expressing itself in an evolution that inevitably leads toward the fulfilment of their inherent possibilities."

It is evident, since evolution is a single process, that there is some universal, creative process back of evolution and common to all phases of evolution —inorganic, organic, mental and social. For Patten, this creative process is "cooperation, or mutual service." This law of cooperation is expressed by the simple fact that when two or more things are brought together into a definite spatio-temporal relation to one another, and act together cooperatively, a new thing appears with new qualities and new cooperative powers of its own which did not previously exist in its constituents. Water formed by the mutual cooperation of oxygen and hydrogen is a new creation with new qualities and possibilities for world service. The single cell is a system of cooperating proteids and other agents, and its distinctive attribute is life. Patten introduces another concept which he calls "creative drift." All the acts of nature form one continuous creative process which "flows out of an unlimited past, through the present, into a limitless future." This one great process, though infinitely varied in local expression, maintains one common direction or "drift" which may be expressed by the word progress. If we extend our concept of progress by looking farther and farther into the past, we approach the beginning and see nothing but a futile conflict of chaos, a primordial simplicity, continuity and uniformity. This is complete "freedom" with the absence of cooperation. Looking forward we pass from a beginning in universal conflict, in vastness, sameness and emptiness to creative fulness and clarity of infinite organization and unified cooperative power.

Patten thinks that the services and rightness involved in the creation of any particular thing always present a more or less pyramidal series with the "more general, elemental, and enduring phases of the creative process at the beginning or base, the fluctuating and special, at the end or apex." This pyramid is a graded series passing from isolation, impotence, freedom and chaos to compulsion, stability, power, unity and perfection; it is a broad pyramid of mutual services and constructive rightness.

Patten's concept will perhaps be made a little more clear if we draw a parallel between it and emergent evolution. Morgan calls evolution a process of emergence, and the new thing an emergent. Carbon bisulphate is an emergent—a higher form of relatedness—which involves carbon and sulphur, both of which have characteristics vastly different from the emergent. Patten believes that when elements are brought together a new thing is formed which he calls a product. This product is the result of mutual cooperation of the elements from which it was formed. Water is a new product formed by the mutual cooperation of hydrogen and oxygen. A further similarity is that of the things assumed as the starting-point for a constructive philosophy. Morgan takes under acknowledgment a physical world in time and space, and God as the Nisus of the process. Patten says that we must assume matter and energy, time and space. Thus the difference here does not seem to be one of concepts used, but of particular terms used. A further similarity is in the diagrammatic representation. Morgan employs a pyramid with space-time at its base, and divinity, theoreti-

cally and individual, at its apex. Patten also employs the pyramid with "the more general, elemental and enduring phases of the creative process" at the base and unity at the apex. Both have concepts at the base and apex which are very similar, and within the pyramid there are gradations or levels.

Now that we have examined the various definitions, theories and philosophies of evolution, we come in the end to close quarters with the problem, namely, the concept of evolution itself. Have we arrived at any definite results? Let us see, first, how the matter stands with organic evolution.

Biology was the first science to lay any strong claim to a theory of evolution, hence it is not strange that many have associated evolution only with organic development. When we first turned our attention to the concept of evolution we were immediately told to go to Darwin or to the biologists for our answer. This we have done, and now we ask, What have we gleaned?

What are some of the great outstanding ideas which we have found in organic evolution? The first is probably the common origin of plant and animal species. Common origin is an idea which we traced as far back as the Greeks. Thales claimed that water was the source of all things. Others of the Greeks named earth, or air, or fire, or even such an indefinite concept as "the boundless" as the source of all things. The great host of eighteenth and nineteenth century biologists all started with the common hypothesis of the single cell from which all the complex forms of life developed. Thus, as we have seen, all the theories of organic evolution seem to have this one fact in common—the fact of the common origin of plant and animal species. This is significant. All life has come from one common "stuff" by some process.

If we assume common origin, immediately we assume common descent, and a genetic relationship between the individuals and the species which have descended. All the theories of organic evolution have assumed these things to be true, and the great burden of their proof is to demonstrate these assumptions and the mechanism or process which will account for them. If they have solved this problem, well and good—but have they?

The genetic relationship of species, the common origin of all plant and animal life, the descent of man from some ape-like stock are ideas that are accepted by men of science at the present time. The study of evolution which we have made in this paper confirms rather than weakens the theory of organic evolution. But, strange to say, this is practically all that is known of organic evolution. Text-books on evolution at the present time are largely devoted, first, to the fact of evolution; second, to the evidences of the fact drawn from comparative anatomy, from embryology, from geology, from zoogeography and from rudimentary organs, and third, to the various theories, or the manner of evolution, the principal theories being those of Lamarck, Darwin's theory of natural selection, De Vries' mutation theory, and various orthogenetic and idioplasmic theories. Of these, Darwin's theory is the most famous, but at present it is passing more and more under serious criticism.

The plain fact is that at the close of the first quarter of the twentieth century, while the fact of evolution is accepted more and more, neither the cause, manner nor meaning of evolution is known.

> At the same time that these biologists accept descent with modification as an actual occurrence in nature, they are most sceptical and reserved about what may be called the driving force behind descent. What is there in nature that has kept in motion this incredible capacity to produce new species? How is it that from age to age large and ever larger floods of new forms have burst forth? To this question no biologist has a clear and unequivocal answer.[6]

[6] Parker, "What Evolution Is," pp. 62–63.

Again we may quote from Bateson's "Problems of Genetics."

The many converging lines of evidence point so clearly to the central fact of the origin of forms of life by an evolutionary process that we are compelled to accept this deduction, but as to most all the essential features, whether of cause or of mode, by which specific diversity has become what we perceive it to be, we have to confess an ignorance nearly total.[7]

Osborn in "The Origin and Evolution of Life" says:

In contrast to the unity of opinion on the law of evolution is the wide diversity of opinion on the *causes* of evolution. In fact, the causes of the evolution of life are as mysterious as the law of evolution is certain.[8]

We could make many more similar quotations from prominent present-day biologists and zoologists, but the authority of these three is sufficient to substantiate our statement.

Because of this fact—that little is known as to the causes, manner or meaning of evolution—the fundamentalist controversy has arisen. Because evolutionists admit their lack of knowledge of the causes, the fundamentalists go a step further and deny the *fact* of evolution. No one would deny the fact that the sap rises in the trees in the spring time, and yet we do not know the causes which are responsible for this phenomenon.

As the scientist and the philosopher usually look for a cause, so we ask, What is the cause of species formation? If we assume that natural selection is the mechanism of species formation, then the question arises, What makes the mechanism go? This question the theories of biological evolution do not answer. None of them assumes any force which is the "push" of the mechanism. This is particularly true of Darwinism. An apparent exception may be seen in the various orthogenetic theories, such as that of Eimer and of the other orthogeneticists, which are very interesting but which merely present a mystic factor that is not enlarged upon. Indications such as these do point in the direction of a philosophy of evolution.

Lastly, we may say that the terms used by the last century biologists are too narrow. They talked of variation, selection and heredity, which concepts can not be employed in general evolution. The development of life—species formation—is only a small part of evolution. Thus the concepts employed by Darwin, Spencer and the others are wholely inadequate when we deal with inorganic, stellar, social evolution, or the evolution of the mind. The process of development is one process and we must use such concepts as will be adequate in all phases of this process.

Thus we have found that many theories of organic evolution have been offered; but still the origin of species remains unknown and the manner of species formation doubtful. Darwin presented an elaborate and most interesting theory which held sway for over half a century; but we have found that it is very disappointing, for as an explanation of the process of evolution it leaves so many unanswered questions that we must honestly say that at the present time we get little help from theories of organic evolution as to the philosophy of evolution.

Since this is a philosophical inquiry into the nature of the concept evolution, and since we get little or no help from the theories of organic evolution, we must turn with great expectation to the "real" theories of evolution, or the philosophies of evolution. What are the philosophies of evolution which we have examined, and what light do they throw upon the concept?

The first evolutionary philosophy which we met was Aristotle's. For him all life, yes, all things, are in a process of becoming. The potential—matter—is being realized in the actual—form or

7 P. 248.

8 Pp. viii–x.

idea. There is no matter without form, and pure form—that which has no matter—is the prime mover or God. This process of realization of the potential in the actual goes from simple to complex with pure form at the end, or shall we say apex? H. W. B. Joseph, in his recent Herbert Spencer lecture, explicitly states that he believes that this Aristotelian concept is the true concept of evolution. He says:

> There is no process of development unless what develops is all the time that which comes to be; and again, there is no process of development unless it is not in the same way so in the earlier and later phases. This is . . . the old account, put forward by Aristotle in the antithesis of the potential and the actual.[9]

Now let us consider the significance of Aristotle's concept of becoming and its similarity to more recent philosophies. Aristotle said that matter is realized in form, thus he assumed matter and form or idea or God, the latter being the prime mover. In the twentieth century philosophies, we find assumptions similar to those of Aristotle's. Bergson assumes matter and mind. Morgan acknowledges matter and God who is the Nisus of the process. Patten makes similar assumptions. Thus the striking fact is that most of the outstanding philosophies of evolution have the same assumptions under different, yet similar, nomenclatures. But the similarity does not end with the assumptions; there is further agreement. Aristotle said that it is a process of becoming—of realization. For Bergson it is a process in which mind is realizing itself in matter. For Morgan it is a process of relatedness due to the Nisus—God—who works through all. Thus we see that not only the materials of the process, but the process itself, is the same in all these systems. The process is the same in every case, but the imagery used in elucidating it is different. Thus it may be that our particular type of imagery has given rise to many difficulties and has been a handicap in our understanding of the process of evolution as it really is. This is merely a suggestion in which there may be hidden considerable truth.

But, be it carefully observed, the philosophy of Aristotle is a philosophy of development rather than a theory of evolution. The process from the potential to the actual is a phrase capable of different interpretations. It might be understood to claim that Aristotle's concept of development is without points of comparison, or it is quite probable that he could have chosen some other phrase which would have expressed his meaning better than the one he did choose. Since the prime mover is a creative and developmental force, attracting rather than compelling, this system appears to be what we should call a theory of creative evolution.

An elaborate and captivating philosophy of evolution is that of Spencer. His famous formula held sway in the realm of thought for a long time, but now it is receding into the background. Why? Because it has not thrown light upon the concept of evolution. People to-day are seeking for an adequate concept of evolution, and as Professor Urban says, "Spencer's formula has proved very disappointing in this respect, and thus it must be laid aside for other and more fruitful suggestions."

Evolution, we have seen, means unrolling or unfolding—the implicit becoming explicit. This is exactly what Augustine believed development was—an unrolling or unfolding with the implicit becoming explicit. Thus Augustine's philosophy is true to the term. But in our study of more recent philosophies of evolution we have found that evolution is not an unrolling but a building-up process, in which something new is constantly added. Thus in the recent systems we find great emphasis

[9] "The Concept of Evolution," p. 14.

placed upon the new and upon creation. The molecule is something new, the crystal is something new, life is a new attribute, mind is a new quality. The new was not implicit becoming explicit; it is a creation, an emergent. The new Ford car was not implicit in the chariots of the Pharaohs; it is the result of a building-up process, each addition being a new creation. The cinema was not implied in any of the ancient civilizations; it is a distinctly new factor in our modern social life. Thus it seems that the term "epigenesis" would be better than evolution since the process is one of up-building. True, but associations have grown up about this term in biology which would make it undesirable. Also it is a forbidding, harsh-sounding word which makes it unpopular. Are there other possibilities? Is there not some other term which would better describe the process? If the meaning of evolution is that it is a creative process, as we believe it is, in which something new appears at every step, then evolution is a process not of unrolling, but of up-building, and every change is a transformation. Thus the French word *transformisme* is a much happier term than the English *evolution*, or the German *Entwickelung*.

Again we may call it organization, for we have seen that the new does not come as a process of unrolling or by a mere addition process, but as the result of organization. This term seems to be better than the old term evolution, but even it is not descriptive of nature's efforts. If we employ this new term organization, we are led to assume some organizing force, a life force, *élan vital*, or a creative God. We have seen that all the recent philosophies of evolution assume or take under acknowledgment some such force. It is on these "formative forces," forces that are creative, cumulative and synthetic, that our interest is centered.

Thus we have come to believe that the problems of evolution are metaphysical. We are at an end of biological philosophies. "The doctrine of emergent evolution and of metaphysical levels means the break-down of naturalistic evolution."[10] "Thought," says Urban, "is in the position either of abandoning the concept of evolution as in any sense a world concept or else making life the ultimate concept." What, then, is the outcome? Just this, that we must first unthink all our nineteenth century ideas and approach the problem anew. We have found that evolution is not an unrolling or unfolding process—the implicit becoming explicit—as the term would indicate, and as we thought; but it is a process of building up, a process of emergence, or a process of creation which we may call, as Dr. Patrick has suggested, creative effort.

[10] Urban: "Progress in Philosophy in the Last Quarter Century," *Philosophical Review*, March, 1926, Vol. 35, No. 2.

REMINISCENCES OF AN AMATEUR BOTANIST

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These reminiscences of botanical adventures will perhaps be considered trivial, even frivolous, by serious readers. An account of them might more appropriately be called confessions and they may have some value as a warning to the heedless.

When I took up my botanical studies, if they can be described by such a dignified term, Professor Edward Lee Greene occupied the chair of botany at the University of California. Among his students at that time were Willis Jepson, V. K. Chesnut, Walter Blasdale and several others whose names have become well known as botanists and collectors.

My first confession is that I took up the study of botany without any particular consideration and continued it without any serious purpose. The occasion of my commencing was probably the fact that my college chum, Chas. A. Michener, had enrolled in Professor Greene's courses, probably to find an outlet for a fertile imagination and a large amount of spare time, neither of which was sufficiently occupied by his prescribed courses. Michener had the remarkable and useful faculty of passing a first section examination in any subject without previous study.

Botany in fact was not a study for us but a sport. We used it not as a means of obtaining credits in prescribed science but as a substitute for football games, track events, writing poems for the *Occident* and similar campus activities. We belonged to none of the recognized schools of botany. We were not physiological nor cytological nor ecological botanists, hardly even taxonomic or systematic botanists. We belonged perhaps to the romantic school of botany. We used the field of botany not as a laboratory but as a play-ground. Our heroes were not DeBary nor Strasburger nor Zimmerman, not even Prantl and Engler, but Theophrastus, Rafinesque and Edward Lee Greene.

The idea of utility in botany was abhorrent to us. If a plant had a known cultural value we despised it. Any plant which attracted the attention of a farmer or of a gardener was characterized by the contemptuous epithet of "vegetable" and we refused even to learn its name.

We spent the first weeks of our first course in learning the technical terms of the game. We were taught by Professor Greene that to speak of "a plant with roundish leaves that grows in the woods" was indefinite. To describe a leaf as peltate, with repand margins, fugacious stipules and tomentose indument was both definite and impressive.

We dabbled later a little in plant physiology and cytology with Professor Osterhout, but these activities were not botany as we understood it.

Later we were introduced to another series of terms by means of which we were to arrange plants in orderly armies, corps, battalions, regiments and companies. We learned the insignia of the armies of the Exogens and of the Endogens, the dress and accoutrements of the *Chloripetalae*, the *Sympetalae* and the *Apetalae*. We learned the position and relation of the *Graminae*, the *Leguminosae* and the *Rosaceae*. We learned shibboleths which enabled us to distinguish a papaver from a crucifer and a labiate from a scrophularid.

At this point we commenced the real business or sport of botany. We were instructed in the art and mystery of collecting. We were shown that the successful collector did most of his work on his hands and knees. We learned that a rest of fifteen minutes on a grassy knoll or the edge of a swamp was often more fruitful in discoveries than a hurried walk of half a day. We were taught that a perfect specimen consisted of a whole plant, including fruit, flower and root.

In our striving for perfection this ideal turned our attention to the smaller forms of the higher plants. With the specifications, it seemed impracticable to prepare perfect specimens of a sequoia or of an *Echinocystis megarhiza*. Later we discovered methods of approximating our ideal even with many shrubs and trees. Some, however, such as most of the conifers, remained permanently outside the field of our endeavors, owing to another limiting rule which confined a specimen to the size of a standard genus cover and required it to be susceptible of filing in our standard cabinets.

We were given certain rules based principally on the structure of the flowers. These flowers we dissected for examination, and interpreted our observations by means of analytical keys. One limitation of this examination was that it should be made with the unaided senses or at most with the aid of a pocket lens. Any character which could be perceived only by means of a compound microscope or of a test tube was of no value. You could not add a laboratory to the pack which a collector was obliged to carry.

The use of the senses was interpreted in a very liberal way. We became expert in detecting families, genera and species by smell and taste. In this, however, our skill never equaled that of Professor Greene, who was enabled to separate the Cichoriaceae from the Compositae and align them with the Lobeliaceae by the facts that the odors of *Lactuca virosa* and of *Rafinesquia* produced nausea in the human species and that Lobelia and Sonchus were eaten with equal relish by the bovine. These facts account for the disdain with which we looked upon the "closet botanist" and his paraphernalia of microscopes and of desiccated and fragmentary type specimens.

Finally, as skill increased, we became independent of rules. By intuition we were able to place a new plant on sight within a few lines or pages of its proper position in "Flora Franciscana." Though there was some loss in accuracy, there was great increase in speed which was of importance in amassing and labeling a large collection. Our ambition at this stage was to possess a herbarium containing all the species of California and most of those of the world.

In determining the exact place of a species new to us, however, we still had to do some humdrum and time-consuming work with analytical keys and descriptions. In desperation we would often take our specimen to Professor Greene and he would usually obligingly furnish us with its name. Sometimes, when he was busy, he would refer us to his favorite and star pupil, now known to all botanists as Professor Jepson.

Professor Greene was inclined sometimes to be mildly sarcastic. Once when I brought him a specimen which had foiled me he remarked, "Why, even Jepson knows that!"

Our method in tracking a species to its lair in the pages of "Flora Franciscana" was, after making a usually successful guess at the genus, to trace it through the species key with occasional reference to the full description. It was essentially a method of determination by elimination. If there were ten species in the key and we satisfied ourselves that

it could not be any of nine we concluded that it must be the tenth.

This method was often successful so long as we confined our collecting to the immediate bay region. On one memorable occasion, however, we were informed by Professor Greene that not only was our specimen not of the species we had chosen, but that it was not any one of the species described in the "Flora." It was, *mirabile dictu,* an addition to the "Flora," a species which had escaped the eagle eye of Professor Greene himself.

Most of the additions made in this way at first were introduced plants and those which we found were much fewer than those found by Professor Greene himself during the same period. We were rather piqued at this and almost suspected him of scattering foreign seeds one year to be found and chronicled as introduced weeds the next.

Our operations, which commenced on the campus, were confined for some time to the hills, plains, cañons, marshes and vacant lots of the immediate vicinity of Berkeley. Its flora was and undoubtedly still is very rich and for many months we rarely failed to add several species to our collections on each trip.

In time, however, we were reduced to the counting of the number of species which we could see in bloom on a trip and to making sets of specimens of any species which we found abundantly in perfect condition for collection. In this way we become very familiar with the species of the Alameda and Contra Costa side of the bay within four or five miles of the shore. We also accumulated a fair collection and a considerable supply of exchange specimens.

To give scope to our ambitions and energy, we were soon obliged to extend our forays. We tackled first the sand hills between San Francisco and the ocean, the hills and valleys, the woods and marshes of the Marin County peninsula and finally pushed our raids as far as Mendocino and Santa Cruz along the coast and to Mount Diablo in the interior.

It was at this time that we first experienced the joy of collecting a new and unrecorded species. This added an excitement and zest to our collecting that changed it from a mere recreation to a serious pursuit. We found that other hunters were engaged in pursuing the same game. We began to look upon them as interlopers and trespassers, especially when we found them invading territories that we had come to consider our own.

In our appropriation of territory our morals and customs were similar to those that prevailed in the division of hunting grounds among the Arapahoes and the Blackfeet. Certain regions we considered our exclusive territory. Other regions we respected as belonging to hunters of friendly tribes. A few inconsiderable regions were held to be common property.

The outer coast ranges and valleys from Mendocino County to Santa Cruz we appropriated unconditionally, with a certain tolerance regarding the San Francisco sand hills and Mount Tamalpais. Contra Costa and Alameda counties we considered common and hardly worth fighting for, the game being practically exhausted. The Sacramento Valley and the Vaca Mountains we respected as the domain of Willis Jepson with whom we were at peace. Certain freak hunters, like Professor Howe, who pursued mosses and hepatics, or Walter Blasdale, whose game was smuts and rusts, were considered harmless and allowed to wander at will. Victor Chesnut we looked upon as an enemy and an outlaw. He had collected a *Ribes* and a *Trifolium* in the Napa-Sonoma Mountains in the heart of our main hunting grounds. If we had known his territory we would have invaded it without

scruple. To capture a beautiful and apparently new *Ribes* in a remote gorge on the slopes of Hood's Peak, to bring it back to camp in triumph and then to find that it had already been branded *Ribes Victoris* was intolerable.

Professor Greene as the Great Chief was of course free from all restrictions. We had too much to gain from his friendship to object to his hunting on our grounds. It was Professor Greene who used the names Michener and Bioletti several times in christening some of our discoveries. For this we were deeply grateful.

It was at this time that the great tragedy of my plant-hunting career occurred. From a distant foray on the San Joaquin River I brought home an inconspicuous plant which Professor Greene pronounced not only a new species but a new genus. He named it and published it as *Biolettia riparia*. Alas! Some meddling investigator examined the specimens and, seeing a chance to scalp the professor, stated that it was an old and introduced plant already named. Professor Greene later acknowledged that the plant was perhaps not a new genus but maintained that it was a new species of so divergent a form that it was doubtful whether it should be retained in the old genus.

Of course I sided with Professor Greene; especially as Michener kindly pointed out that a mistake of this kind made my name ineligible forever as a generic name and spoiled my chance of standing beside the prototypes of *Vancouveria, Zauschneria* and *Eschscholtzia*.

During all this time we were continually adding to our herbarium by collection and exchange. We found that new and rare species were in particular demand. In fact, a single specimen of a rare species often secured us several new names for our herbarium. Some of these species had a very limited range or perhaps only a single locality. We were tempted to try to corner the market. We laid dark plots to collect a large supply of specimens of the rarest and then to exterminate the species. I am glad to be able to say that we never carried out any of these plans.

After about two years of active collecting, our herbarium began to assume the proportions and characteristics of white elephants. I was labeling and arranging mine, receiving and sending off bundles of exchange specimens during every spare moment. Michener had the advantage of possessing a well-trained and accommodating mother and sister, who did much of the work for him. At length we were forced to the conclusion that a man who had to make his living must either give all his time to botany or much less than we were giving. We decided, therefore, to combine our collections, to get rid of all our surplus specimens and to cease exchanging. This enabled me to do a little college work and graduate. We could not give up botany altogether, however, but swallowed our pride and changed from collecting to "closet botany." We spent what time we could spare in studying our collections, the collections of others and the literature of the subject.

It was at this period that we experienced the joy not only of finding a new species but of describing and publishing it. New species were hard to find, but we published several. I am not sure whether other botanists accepted our work—botanists are a jealous tribe—but we had great confidence in it. If my name was ineligible as a genus name there was no limit to the number of specific names it might follow.

We soon found that there were much more prolific ways of having your name attached to species than by finding or describing new ones. There were several schemes.

One was to take an old recognized species and split it up into a number. We found that one ingenious operator had taken the common blackberry of England and divided it up into twenty-five or thirty packets, all but one of which he named and to which he thereby obtained the right to attach his name.

Another scheme was to combine or divide genera. It was evidently possible by this means to bag an unlimited number of species. Professor Greene was very skilful at this game.

A most excellent and fruitful scheme was to take a Linnaean genus and give it a name which it probably had in the Middle Ages. In this way one could appropriate even the common or garden vegetables. This, however, required an amount of learning and research that daunted us. Besides, Otto Kuntze had already made this game scarce.

All these schemes, however, had one great objection. They irritated your fellow botanists. It disturbed their ideas, especially those of the amateurs. It depreciated the value of the stock of knowledge in which they had a painfully acquired vested interest.

Chas. Michener, with his usual ingenuity, contrived a scheme which was free from all the objections to these schemes and at the same time was easy of application and fruitful beyond any of them.

It was similar in principle to the devices by which astronomers are enabled to announce the existence of stars before their actual discovery and by which chemists reveal the qualities of elements and compounds which no man has seen or handled.

Michener based his invention on observed facts of current botanical taxonomy. A genus is a group of plants having certain fundamental characters in common which distinguish them from all other plants. These characters indicate a relationship which it is convenient to recognize by uniting the plants of the group under the same name—the genus name.

In this group are smaller groups, each of which has certain other less fundamental characters by which it is distinguished from all other members of the genus group. These smaller groups are called species and each is given a specific name to which the author is permitted the honor of adding his own.

Michener noted in analyzing the descriptions of specific differences in various floras that the number of characters relied on to distinguish a species were few. While the description might be lengthy and the characters mentioned many, most of them differed from those of a closely related species by variations in degree which overlapped. The essential differences in kind were usually few.

Michener, in order to initiate his scheme, which we were convinced was destined to work a complete revolution in systematic botany, prepared a test manuscript.

"I have here," said Michener, in presenting his manuscript to Professor Greene, "the description of a new species of Burbankia which I would be glad to offer for publication in *Erythea.*"

Professor Greene read the description and remarked, "This appears to be a well-marked species. I should like to see the type specimen. Where did you find it?"

"It has not yet been discovered," replied Michener.

"Not discovered! Well, then, there is no such species. How can you describe what doesn't exist?"

"Allow me to explain, Professor Greene. It is really very simple. I have noticed that in your monograph of the genus Burbankia you have described and named two species, *B. concinna* and *B. amoena,* which so far as can be learned from the descriptions differ

only in the shape of the leaflets. In *concinna* the leaflets are linear lanceolate; in *amoena*, linear obcordate. Now my species, *B. decora,* differs from both of these simply by the fact that the leaflets are linear spatulate. It has, therefore, equal standing with the other two."

"Nonsense! Young man, you are too modest. The difference is much greater. Your plant does not exist and therefore has no leaflets at all."

"Your observation, Professor, that it does not exist may or may not be correct but in any case it is not a valid objection.

"In the first place, you may be mistaken. It may exist and only be awaiting a more thorough search of our flora. In the second place, if we examine carefully the fossil flora of the world we will find that few or none of the species described by Linnaeus, Bentham and Hooker, Asa Gray or even by yourself, Professor, existed a few hundred thousand years ago.

"This examination, if done critically, however, will reveal numberless species closely related to those of the present day. Many differ no more from species of the present day than does *Burbankia amoena* from *B. concinna.* An alert and acute botanist in the age of *Sequoias* could easily have foreseen and described one or more of the essential specific differences of *S. gigantea* and *S. sempervirens,* even though these modern species did not then exist or were so rare that they had escaped the notice of the most active collectors of the time. An unusually learned monographer might even have foreseen *Biolettia riparia.* Therefore, we have every reason to believe that in the next hundred thousand or million years evolution. . . ."

"That is enough, Mr. Michener. If you are serious, it is evident that you have a most deplorably false conception of the world and of its origin."

Professor Greene was probably not convinced of the theory of evolution. The manuscript was not accepted.

Thus was an idea of unlimited possibilities stifled and the career of a brilliant taxonomic botanist blighted at its inception.

The idea was perhaps not altogether original with Michener. There is evidence that it had already been conceived and used by Samuel Constantine Rafinesque, who lived in the early part of the last century.

Rafinesque is the author of a large number of works on botany, conchology, paleontology, anthropology, history, viticulture and most other profound subjects. The monumental character of his work is indicated by such titles as: "The American Nations, or Outline of their General History, Ancient and Modern, Including the Whole History of Mankind, etc., etc."; "*Antikon botanikon;* or Botanical Illustrations of 2500 New, Rare or Beautiful Trees, Shrubs and Plants, etc."; "*Neogenyton;* or Indications of Sixty-six New Genera of Plants of North America."

That a man should find and describe such a vast number of genera and species was remarkable. Some considered him insane. Others explained it by his travels and collections in wild regions inhabited only by hostile Indians and where no other botanist had been hardy enough to penetrate. This explanation is rendered probable by the fact that some of Rafinesque's plants have since been discovered and his names accepted. It is hardly possible, however, that so many undiscovered species and genera still exist in the United States.

Michener's explanation is the most plausible. Rafinesque, according to Michener, simply described species and genera which his observations and intuition told him might exist or, if they did not, would undoubtedly be brought

into existence in the orderly processes of evolution. Rafinesque thus not only anticipated Darwin, but was far in advance of even the most modern of the Neo-Darwinians.

Michener was quick to perceive the immense possibilities of Rafinesque's method and often described to me the way in which he proposed to develop it.

Any form of plant is possible, in fact, given unlimited time, all forms are inevitable. Some, however, will require millions or trillions of years to evolve. The pressing and interesting matter is to foretell and describe those which will evolve in a few thousand years or less.

To do this all that is necessary is to determine exactly, by a careful study of geology and paleontology, the general character and direction of evolutionary changes in the various orders, families and genera. With these data and the well-known device of extrapolation, it is perfectly simple to determine in their main outlines the characters of future species, genera and orders. "If this work is carefully and skilfully done," he said, "and on a sufficiently comprehensive scale, the systematic botanist of the future will have no need to dispute about names or priority. All he will have to do is to search for type specimens and place them in the proper pigeonholes, labeled with the correct names which I will have already prepared for them."

How much work and uncertainty would have been saved to the botanical clubs of all times if this great and original ideal had not been demolished by the untimely orthodoxy of Professor Edward Lee Greene!

THE MUSEUM OF SCIENCE AND ITS RELATION TO INDUSTRY

By Dr. F. C. BROWN

DIRECTOR OF THE MUSEUMS OF THE PEACEFUL ARTS, NEW YORK

In any type of museum there is some purpose toward which it is aiming, but quite frequently the service that a museum renders may be more important outside the field of its main endeavor. However, it makes for efficiency if the purpose can be defined and the resources of the institution can be corralled to meet the main purpose.

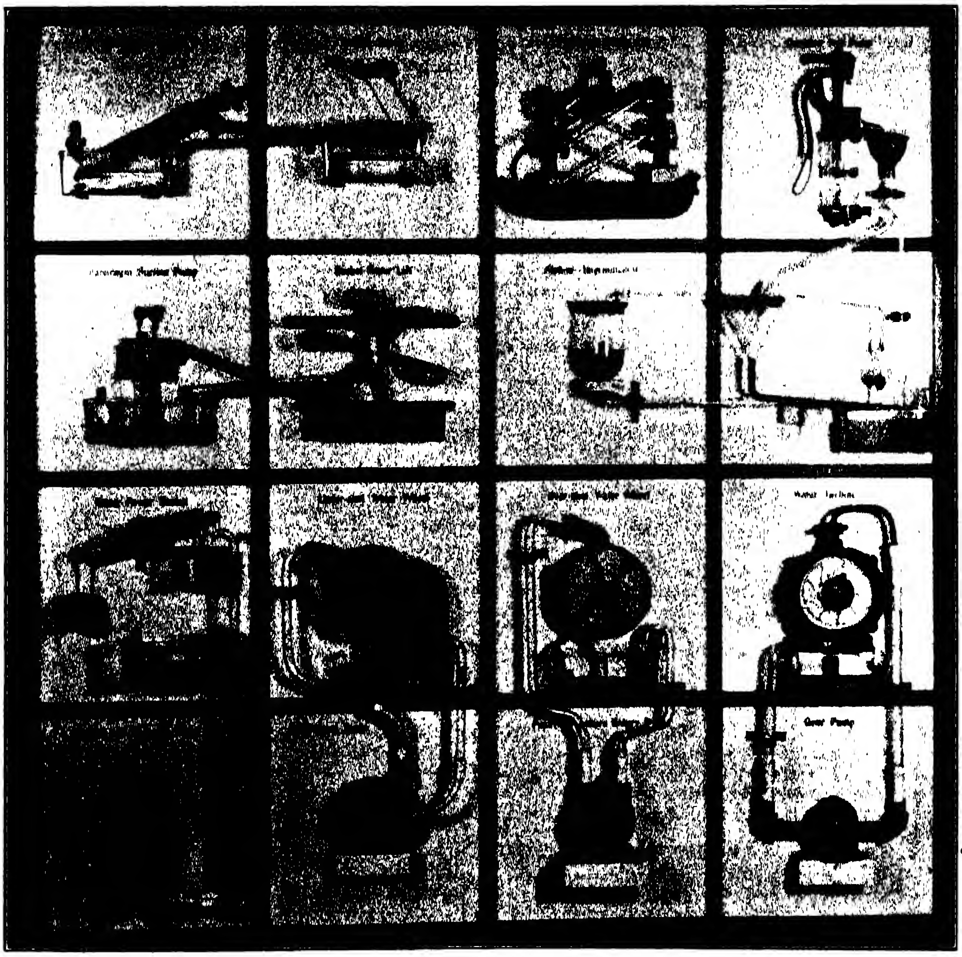
In the old sense a museum was regarded as a depository primarily, and secondly, as a place of research and education. I propose to picture to you the museum of science primarily as an educational institution, but one which makes use of the principles, laws, processes and achievements set forth in their historical relation, and if this picture is well presented, it should be clear that the museum is, in a way, the warp and woof of industry.

This museum differs fundamentally from our universities, colleges and high schools in that it is freer and more democratic, and quite inadequate for purposes of developing moral and mental qualities which come from regular classroom work with punishment and rewards of certificates and diplomas for excellence. I do not anticipate that the museum will give a course in calculus or geometry, or that it will even teach the multiplication table. It is apparent, therefore, that the museum can never be a substitute for a college education. It can, at its best, only aid the other educational institutions and fill educational gaps in the development of the layman. It follows that the museum as an educational institution must necessarily have exhibits which attract as molasses attracts the fly. The museum director must not only be a man experienced in science and education, but he should also master practical psychology and the art of showmanship second only to Mr. Barnum.

The permanent location of the industrial museum should be near the transportation center, where all the schools of the metropolis can reach it most advantageously and also where the thousands of daily travelers from outside the city may find it easy to utilize an extra hour or an extra day. It is axiomatic that any newsboy or any policeman should be able to direct the stranger to the museum and that a minimum time should be required to reach it, without the fear of going astray. You will quite agree that building an industrial museum worthy of the greatest industrial nation is no small task.

The great purpose of our industrial museum is to interpret our mechanistic age for all classes and professions. Words, however well expressed, can only give a vivid understanding when first-hand experience furnishes a background. This is a huge undertaking, but perhaps not as difficult or complex as that of the Rosenwald Museum, which proposes a social interpretation for the visitor in addition to the technical exposition.

The man who has climbed to the top of a high mountain and viewed the snow-capped peaks beyond is the only one who can know the ecstasy of the mountain view. He who has lost a dear friend is best in position to understand the meaning of such a loss to others. He who has worked twenty-four hours consecutively

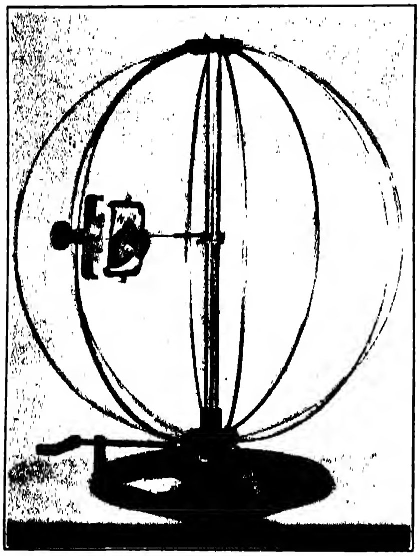


BY PRESSING THE BUTTON

THE VISITOR CAN SET IN OPERATION THE ABOVE SIXTEEN WAYS OF HANDLING FLUIDS. THESE WORK IN PAIRS. FOR EXAMPLE, A BAILING SCOOP FURNISHES WATER FOR ARCHIMEDES SCREW AND THE ARCHIMEDES SCREW RETURNS THE WATER TO THE BAILING SCOOP.

knows best the meaning of work, and he who has been truly hungry for a long period understands hunger pangs. The man who has lived with the stars on the lonely prairie or in the astronomical observatory gets much more understanding of the vastness of space than one who reads any quantity of books without observing the stars or any of the physical phenomena connected therewith. If the book student has only seen the stars at night and has observed the spectra of gases in the laboratory he will have greatly improved his possibility of understanding.

In the vast divergences that our industries have taken with myriads of machines, what hope is there that man can understand to-day and to-morrow the meaning of things? Language at its best is so inadequate to convey the ideas where there is lacking the background, even if we had unlimited time to read. Thus the industrial museum comes in to fill the gap, to portray the growth of the industries and the underlying sciences



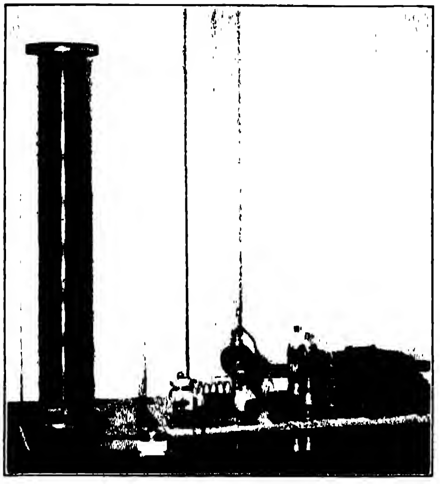
SELF-DEMONSTRATING MODEL OF THE GYRO COMPASS
THE RUBBER BAND MAY BE USED TO REPRESENT GRAVITY.

for the common understanding of all people.

Before stating the aim of the museum of science as a basis of an educational institution which serves industry at large, I would like to give the philosophic background. You will recall that our ancestors for centuries upon centuries were herdsmen who gazed at the stars by night and wondered. This wonderment led to the development of astronomy, and mathematics was developed early as a handmaid thereto. Thus, astronomy and mathematics should be the background of a museum having to do with the physical sciences and industry. It is the way the race began.

If we study carefully the ancestors of man as the science of astronomy developed, we will get our cue for the basis of deep interest in all lines of the science museum. Regardless of how busy men are, whether in manufacturing, mining, agriculture or business, they yet exhibit a latent interest in the unknown forces of nature, whether in the atom or the stars, that is just as deep-seated and more far-reaching than man's interest in the prizefight, baseball or football. I believe the reason is clear, namely, that just as man for centuries has taken a keen interest in the development of those qualities manifest in the prizefight and baseball, for just so many centuries his mind has been engrossed with the desire to extend its mental horizon, to know what is in the earth and under the earth. Perhaps there is only one greater allurement for man, which is, to see beyond the end of life. I regret that the science museum, so far as I can visualize, never will be competent to open the door to this greatest allurement, but every other

THE VISITOR DRAWS SMOKE INTO THE CHAMBER IN THE MICROSCOPE
BY USE OF THE BULB, AND HE OBSERVES THE MOTION OF THE PARTICLES DUE TO MOLECULAR BOMBARDMENT. THE MOTION IS KNOWN AS THE BROWNIAN MOVEMENT.



A SMALL RADIO SENDING STATION WHERE ONE CAN PRODUCE VISIBLE STANDING RADIO WAVES.

phase of extending the bounds of the unknown is open to the museum of science, both as a means of alluring the visitor and as a means whereby his attention will be held and his education improved.

It is not only the small boy who eternally demands "why?" and "how?" for the adult also wonders, when he sees a mechanical marvel, how is it operated, and the science museum answers his questions better than any long technical explanation, which, in many cases, would go far over the head of the average questioner. For example, a man in Grand Central Terminal sees the transatlantic plane *Bremen*[1] suspended above New York's first railroad train. As he gazes at this historic plane, many questions naturally run through his mind, particularly if he has the time to daydream. He wonders how one small propeller can carry such a huge object in a non-stop flight across the Atlantic; he wonders how much air speed is attained, and the relationship between the air speed and the lifting power. He may even wonder as to the rising speed of the plane when it was loaded with 8,600 pounds' weight, and its landing speed when its gasoline was nearly exhausted so that it weighed less than 3,000 pounds. He may wonder as to the principle of the instruments that made this air speed known to Colonel Fitzmaurice and Herman Koehl. He is likely to wonder how the aviators knew their altitude, their position in space, and many other similar questions. The visitor can answer many of these questions for himself by operating exhibits in the Museums of the Peaceful Arts. Not only is there a Fairchild aeroplane in which he can sit and see some of the things that happen, but outside the plane there will be individual exhibits which will explain most of the mysterious principles and instruments involved in an aeroplane.

As we all know, about a century ago the science of astronomy in a measure began to give way to the development of the other sciences, so that following after astronomy and mathematics the museum of science should show the elements of the other sciences, and it is common knowledge that out of these sciences has

WITH THIS, THE VISITOR MEASURES THE BURSTING STRENGTH OF SAMPLES OF PAPER

[1] This historic plane will at a later date be a centerpiece in the aviation department of the museum.

VISITOR OBSERVING THE AIR SPEED AND CORRESPONDING LIFT OF A MINIATURE AEROPLANE IN WIND TUNNEL.

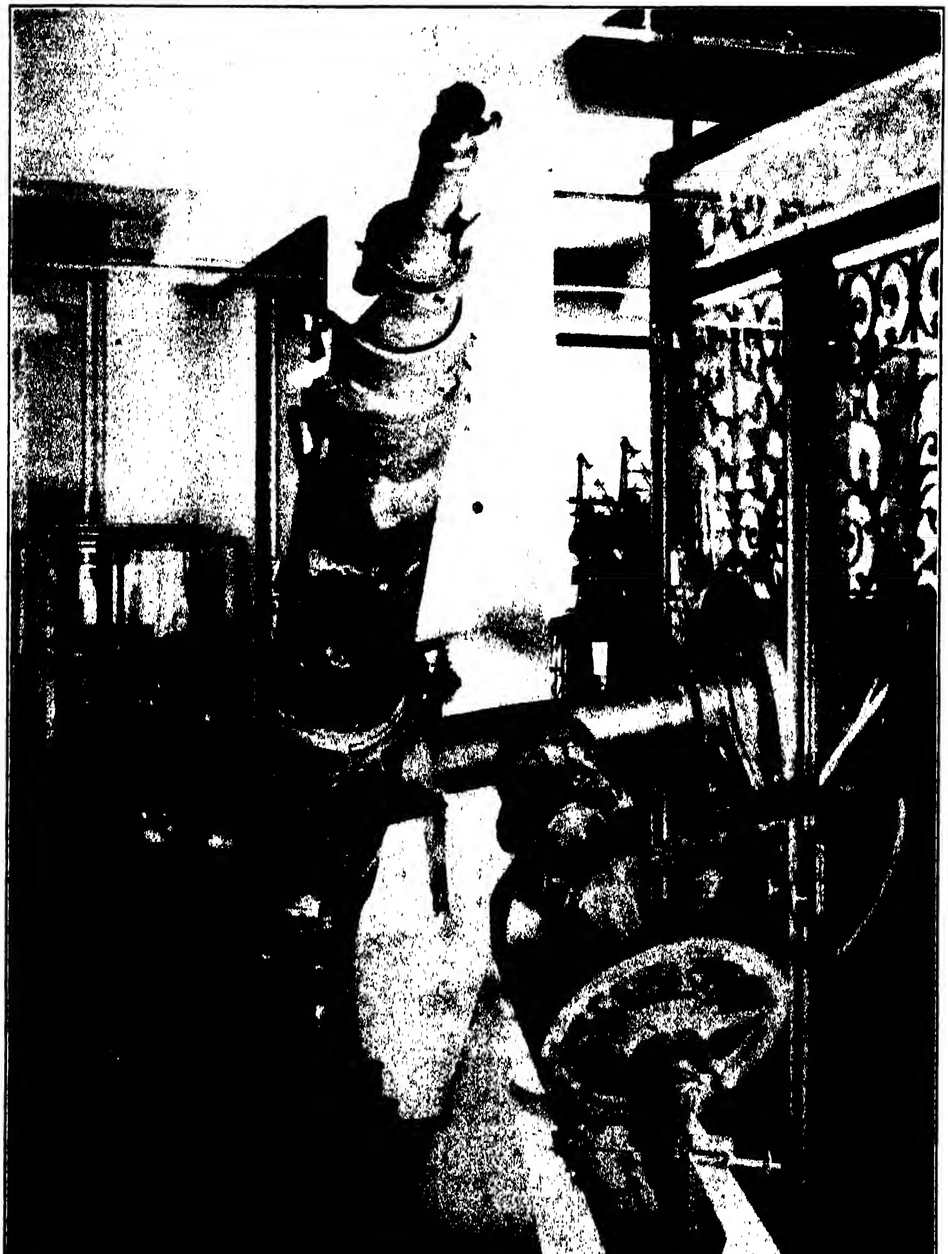
grown an industrial age the like of which the world has never before even dreamed. You well know the automobile, the aeroplane, the telephone, the radio, the skyscraper and thousands of industries are made possible in every state to-day as a result of scientific research. Any industry, not excepting agriculture, that does not avail itself of the benefactions conferred by science is in a bad way, and the conclusion is axiomatic that an industrial museum which is both attractive and educational can do its work best if it features well the elements of industry, which are the elements of science.

If you wish to know what makes the skyscraper possible, you will have to look farther than the architect, and study the laws of brick and steel and electricity.

There is another basis of attraction which is also quite deep-seated. It is the more sordid one which concerns the economics of our daily living. If the museum of science can train the layman to be more intelligent in his daily activities, so that he can be a more useful citizen or so that he can better supply his own needs, it will cause the public to flock to its doors fully as much as it does to the department store or to the trade show. One needs only go to the radio show or the aviation show to find that there is considerable human interest in the things that concern our daily life. In the museum of science the visitors can learn much concerning food in relation to personal well-being. In Munich I observed recently that the food exhibit had more attracting power than all the other exhibits in chemistry. If the visitor can learn the elementary properties that make an article of dress meritorious, such as qualities of wear, qualities involving cleaning, qualities of color,

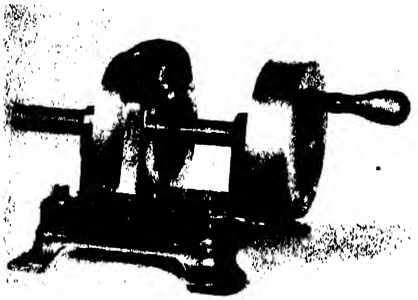
VISITOR OPERATING A MODEL OF THE KILL VAN KULL ARCH

AND OBSERVING THE DEFLECTION OF VARIOUS PARTS OF THE BRIDGE. WHEN COMPLETED, THIS WILL BE THE LONGEST ARCH IN THE WORLD.



AN OLD TELESCOPE

ONE OF THE TWO USED BY RUTHERFURD TO TAKE PHOTOGRAPHS OF THE MOON AND THE CONSTELLATIONS.



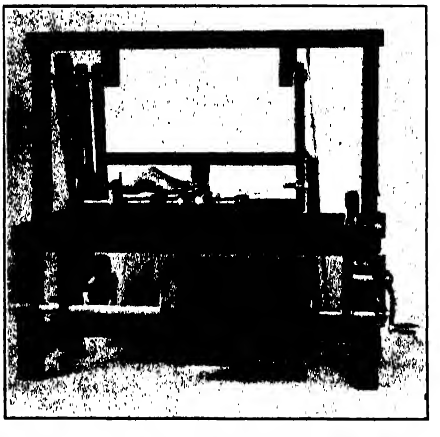
ONE OF EDISON'S EARLY TINFOIL PHONOGRAPHS

such as fastness of color, color harmony and the like, he will be able better to make his pocket-book meet his income and to reduce the waste arising from the manufacture of inferior products.

If the manufacturer and the laymen learn the relative value of bursting strength or tensile strength as applied to hosiery or linen, the waste in manufacture can be very much reduced, and more important than this, the waste in distribution; for I am making the statement without fear of contradiction, that the greatest need of the manufacturer to-day is to have a more educated public or at least a public that is more readily educated.

The manufacturer uses billboards, hand bills, and many objectionable methods of advertising, only because he must, and so on with all the things that people buy to meet their needs. They buy what is placed before them; they do not know, and frequently the manufacturer himself does not know, what is best for the individual. The presentation of museum exhibits which will show our public by the instruments of science and engineering what is best will attract considerable interest.

Then there is a further basis of attraction in the science museum, and that is to employ the instruments of science to determine personal characteristics of the individual. Everybody likes to know little details about himself. If the visitor could measure the elements of his racial characteristics, this would be more popular than the soothsayers of old. However, we can not do this yet, but we can use modern instruments to measure other qualities. I will mention only a few of these. The visitor can measure his weight and height, the color of his hair, the shape of his hair, in comparison with that of different races, he can measure the color of his eyes, and the inter-pupillary distance. He can measure his perfection of hearing, and the limits of his audibility, both for high pitch and low pitch. He can measure the electrical resistance of his skin and the electrical resistance of his body. He can measure his lifting power, his gripping power. He can measure characteristics of his heart beat. He can see the wave form of his voice and measure his lung capacity. He can measure his visual acuity to light of different intensity, he can measure his reaction time to electric shock, his reaction time for seeing and his reaction time to sound. He can measure the temperature of his hand with an automatic electric thermometer, he can measure the radiation



A WORKING MODEL OF THE BLANCHARD LATHE

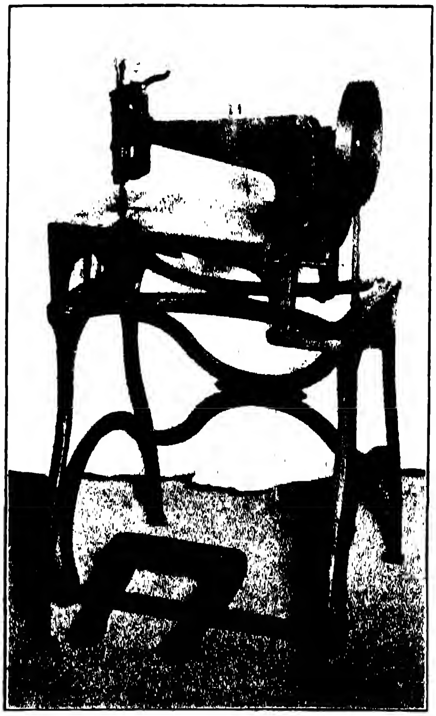
FIRST USED FOR REPRODUCING GUN STOCKS FROM PATTERN.

SEWING MACHINE
USED BY MRS. WILLIAM TAYLOR FROM 1862 TO 1926.

from his face as well as the temperature of his blush.

All of these exhibits, and many more, will not only attract the visitor, but will also give him information which will be a challenge to his imagination and may be useful to him.

You perhaps have been wondering if the museum described here is to be quite devoid of all the relics which in days of yore were the only reason for the existence of a museum. While we are convinced that there is considerable general interest in relics as such, we nevertheless believe that to the average individual relics are of most interest when they are portrayed in connection with their use; that is, an old machine is most fascinating when the visitor can see it operated, or some part of it operated, so that he may see the reason for its existence when it served a useful place in its field. In general, a working and sectioned replica is more useful for our purpose than the priceless relic which can not operate or be touched. However, the museum should have on public display a great many old relics which would serve as centerpieces to exhibits, somewhat as floral decorations are useful in the dining-room. Moreover, there should be many more relics preserved in the archives of the museum, in the same way that books are preserved in the stacks of a library. Such exhibits should be available to the expert or general visitor upon application to the museum office. These, in general, should be housed with regard to the greatest economy of space rather than with regard to the most attractive display. It is my personal opinion that the great national relics in industry, which have priceless value, should in general be housed in the National Museum at Washington. The main purpose of the museum here described is to provide education to the general public as well as to serve as an aid to schools. The general public are treated as laymen alike, and the man of seventy is sup-



AN OLD HOUSE SEWING MACHINE OF 1854
ONE OF THE EARLIEST COMMERCIAL TYPES.

posed to have the same interest in the fundamentals of machines as the boy of seventeen. If, therefore, the museum takes the boy of seventeen as its norm, it will not go far wrong. We should educate our general public not alone because of the general pleasure in obtaining information in an attractive manner, but also for the general good. The banker should know the better and safer uses for the investment of money, the manufacturer should learn of developments in lines akin to his own, in order to improve his own product or the method of its making; the preacher should have an understanding of the mechanisms of his age, in order that he may know better the commonality of his audience. Our civilization is growing faster than any mushroom, and if we are to have a general culture, that culture should consist in its elements of permitting our general public to see the poetry in our modern machines, and that poetry emerges when they see how the velocity of light is measured, how color harmony is produced, how electricity travels, how atoms break up and all those mysterious forces that underlie our age of machines and that furnish a possible basis for all unity in our mechanistic age.

Since the industrial museum is to be an authoritative clearing-house of basic information, useful to all the industries, it would seem to follow automatically that it will be in a degree a research institution in its field, just as the American Museum of Natural History has done research work in its field. However, this will depend largely upon the enthusiasm of the experts in the different departments. Already the Museums of Peaceful Arts has had demands for information that have been the incentive to investigate unknown fields. Experience will doubtless prove that an exposition, as its new and major opportunity, will require a rather complete and exhaustive use of its resources, and that the demands for new information can generally be most economically satisfied by reference to and by cooperation with other existing institutions which have research as the primary function. On the other hand, one of the great services of the museum will be to find and to inspire young men to fill useful places in all the industries.

FITTING THE COLLEGE TO YOUR BOY AND GIRL

By Dr. ALBERT EDWARD WIGGAM
NEW YORK, N. Y.

Nearly three quarters of a million young men and women are now in the colleges of America, and the following five things represent about the situation they are in and about what is happening to them.

The first fact of the situation is, that if you should see an ox-cart, a covered wagon, a day coach, a Pullman express and an aeroplane coupled together behind one engine, you would have a fairly just picture of the average American college. The engine is the college professor—pulling, tugging and puffing away, trying to pull all this conglomerate assortment of vehicles along at the same speed. And there are three distinct tragedies which result. The first is, the professor is succeeding; the second is, he is proud of it, and the third is, instead of traveling at the aeroplane rate, as the professor fondly imagines, the whole educational train is going at little better than the ox-cart speed.

To apply the foregoing picture: in many colleges from top to bottom, and to some extent in all colleges, the fast boy and girl, the average boy and girl and the slow boy and girl, the motor-minded, the abstract-minded, the artistic, philosophical and mechanical-minded boys and girls, are all given very much the same educational dose.

This type of professor proceeds on the theory that the boy and girl must be made to fit the college, whereas the new educational science says that the college must be made to fit the boy and girl. The students by the old theory are in the main treated as though they were all born equal, notwithstanding that all men are born unequal. It is the business of education to draw out these inequalities and make them more unequal. As one philosopher has said, there is one point on which all men are exactly alike, and that is they are all different. Education should develop these differences, and make them into larger and more effective differences. Yet, the average college professor has not the slightest idea of the magnitude and fixity of these individual differences, and, as a consequence, does not know what his own job really is.

The second fact is that the college is not nearly big enough. It is built for aristocracy, instead of democracy. Only a fraction of 1 per cent. of the American people now get into any institution which could by the utmost generosity be graded as a college, and only a fraction of those who do get in ever get out with a college diploma. The colleges could and should serve at least three to five times that proportion of the American people.

The third fact is that a large number of young men and women are now in college who ought not to be there. Some have ability and lack interest; some have interest and lack ability; some lack both. Many of them could not possibly achieve graduation, and even if, by some miracle, a college course could be forced into their heads, it would not pay either them or the country nearly as big dividends as to have them during these years in business or productive industry. The other side of this fact is that large numbers of young men and women are not in college who ought to be there.

The upshot of it all is that we have no such thing as a national system of selecting and encouraging the young people of the country who could and should go to college.

The fourth fact is that the college is built on what scientists call the "all-or-none principle." It says to your boy or girl, "Four years or nothing. Take our whole educational dose, complete our course, whether it fits you or not, or else go home in disgrace." Partly as a result of this, in many colleges, one half of all the boys and girls who start do go home in disgrace. Not much over half the freshmen ever get through to graduation.

The fifth fact represents the big task which lies ahead in American higher education. It is right here and now, and the college of to-morrow must meet and solve it. That task is educating each individual according to his own endowments and needs, and at the same time keeping up mass production. We must face the fact that the colleges are going to be from two to five times as big as they are now, yet they must at the same time devise systems of instruction and college and university plants which shall save, refine and make effective each boy and girl's personal fineness, uniqueness and peculiarity, a system which shall make each student happy, successful and good at his own private personal level of capacity and desires.

In the future every college that fails to do this will be what many colleges are now, mere factories for grinding out a standardized human product that is all too frequently a misfit in modern life.

In fact, the colleges are to-day grinding out so many misfits; they are struggling vainly to give an academic education to so many students who have no business to be there and putting so many others through courses that actually unfit instead of fit their abilities and temperaments that whenever I see the horde of incoming freshmen, many of whom do not know why they are there and will likely never find out, many others who ought to be there but who are going to be wrongly placed and untrained instead of trained, yet all possessed with a blind faith that somehow the college is going to fill their heads with the knowledge that leads to power—whenever I see this ill-assorted conglomeration of hopeful youth, they call to my mind the young lady who said to her physician, "How soon will I know anything, Doctor, after I come out of the anesthetic?" "Well," replied the doctor, "that's expecting a good deal from an anesthetic." I leave the college professor to make the application.

These impressions of the present status of a great deal of American so-called "higher" education are by no means entirely original with me, but are quite largely the result of several years of friendly acquaintance with Dean Carl E. Seashore, head of the department of psychology and philosophy and dean of the graduate school of the University of Iowa. I have also recently spent two entire days with Dean Seashore, devoted to an intensive discussion concerning his five-year study of American higher education—a study which he has been carrying on as the field representative of the division of education relations of the National Research Council. During these five years, the dean has visited more than one hundred and fifty of the American colleges and universities, and has held prolonged conferences with the faculty, going minutely into problems and methods of educational administration and practice. It is the most extended and important survey of American higher education that has ever been made.

Every parent, professor, philanthropist and taxpayer, as well as every boy and girl who is contemplating the great adventure of going to college, will find the report of this survey, now published

by the University of Iowa under the title, "Living and Learning in College," a mine of information and inspiration. Dean Seashore has been a research and educational leader for nearly a generation. He found something good at this institution, and something good at that. To these findings he has added the experience and originality of his own genius. The result is a constructive program for American higher education of lasting importance.

This survey was first undertaken under the auspices of the National Research Council as "The Gifted Student Project." Experience soon demonstrated that what was good for the gifted student was equally good for the good student—for any student who was willing to work. It has thus become a new national program for all boys and girls who are willing to work and study; for all professors and administrators who are willing to learn something new, or to embody the best practice that has been tried out anywhere. If carried out, it simply means that the American college is going to be made over to fit the student's individual needs, intelligence, interests and character, instead of, as heretofore, trying to make the student fit the college.

Even an educational report can have a soul, and the soul of this report is embodied in the motto which Dean Seashore has developed, and which would do well to be blazoned above the doorway of every school and college. That motto is: *Keep each student busy at his highest natural level of successful achievement in order that he may be happy, useful and good.*

Every word of this motto stands for such a broad principle that we should consider the key words for a moment: "*Each*"—that means each individual and not the mass; "*his*"—his own personal qualities and not those of somebody else; "*highest*"—in many colleges it is a disgrace for a student to do his best; "*natural*"—his natural endowment and not some professor's notions of the endowment he ought to have; "*achievement*"—education must have definite achievement as its aim; "*happy*," "*useful*" and "*good*"—education that does not make happy, useful and good citizens is not worth the paper it is printed on.

As to what this far-reaching formula means, I prefer that Dean Seashore should tell you in his own words. As I think back over our two-day discussion of this whole reformation of American higher education, the dean said to me on this phase of the project:

> This formula cuts at the root of one of the most pernicious theories of all educational systems. That theory is, that where the great Creator has failed to make all human beings equal, it is the business of the school to make them equal.
>
> In order to justify this improvement on the Creator's ideas, the schoolmen have found cover under five arguments, which many of them are still advancing with disastrous persistence. These arguments are, first, that this procedure works towards a democratic ideal; second, that it represents the rights of individuals; third, that it is good for the lowly individual; fourth, that it is justified by results, and fifth, that it is necessary for the operation of educational machinery. Each of these is an alibi, and represents a fundamental error and misconception of fact.
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> In answer to the first argument, the true democratic ideal is not equal distribution to all, but *equal opportunities in proportion to capacity*. The second argument is just as fallacious; individuals do not have equal rights either in education or anywhere else in life. The genius and the moron do not have equal rights to wealth, social privileges or knowledge. They do have equal rights in proportion to their capacity to create and enjoy these things, and one should be just as insistent upon his rights as the other. The slow student should have his chance, but he should not be allowed to interfere with the fast student's having his chance; and, of course, the reverse is equally true.
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> But your instructor with a glow of charitable, and what he thinks is democratic, sentiment, advances the third argument. He says, "It is good for the poor student to hear the good

student recite.'' The fact is, it is not good; the humiliation of the poor student in the presence of the good student is often heart-rending. If the facts recited are at the level of the good student, they are totally beyond the comprehension of the poor student, although the latter often assumes an attitude of rapt attention as a defense device to conceal his feeling of inferiority. If the facts are at the level of the poor student, they are of no interest to the good student. The recitation moves too fast for one and too slow for the other; it is, thus, a gross injustice to all.

The fourth argument, that this procedure is justified by results, has a superficial appearance of truth. This is because the instructor does, in a measure, correct what he thinks was the error of the Creator in having failed to make all college students equal. He does succeed in making the gifted student and the slow student so nearly alike that when they come out of college it is difficult to tell the two apart. But it is always because he has dragged the good student down; the poor student can not be raised above his own natural level. As a result, the superior and inferior students come out of college very much alike.

As to the fifth argument, you will see as we proceed that it is not only not necessary to the operation of educational machinery to treat all students alike, but that it clogs the whole educational machine, and results in injustice to all concerned.

It is obvious from the foregoing remarks that this whole new educational program has two great objectives: first, individual attention to each student in order to develop his highest effectiveness, and second, keeping up, indeed constantly increasing, mass production. To achieve these aims Dean Seashore believes that some radical reforms are necessary.

In order to visualize these reforms, let us first ask ourselves how Johnny and Mary ever arrive at college, and what happens to them the day they get there. There has been talk in the home for years about their going to college. Neighbor Jones sent his children, and what is good for Jones's children must be good for Brown's. There are very often other considerations involved, but most students arrive at college through social custom, parental ambition, a prosperous country, accident and the grace of God. A few come from genuine love of learning.

Now let us follow Johnny and Mary through the first week of college. They plunge into a general pell-mell of registrations, entrance examinations and the like, resembling an educational riot, or the mob at a home-coming game. In proportion to the size of the college, from 200 to 3,000 freshmen are herded (there is no other word) into classes, fraternities and dormitories. As to what courses, what instructors and what social groups a student becomes identified with, these are largely matters of chance. Everything is at feverish heat.

From this exhausting process many go home marked as failures. As the year proceeds, from 5 to 50 per cent. of the remainder are sent home. During the sophomore year another group is eliminated; scarcely more than half ever graduate. The students who fail go back home discouraged and disheartened. The whole thing is an orgy of waste in money, energy, hopes and ambitions.

''Now, for all this mêlée and pell-mell,'' said Dean Seashore to me, ''our program provides simple, inexpensive, and, we believe, complete remedies.

''The first remedy is one that we have already demonstrated here in Iowa will work successfully. Instead of letting vast numbers of students graduate from high schools in June and probably waste most of the summer, and then go to college and find out they can't do the work and be forced to go home, we shall select the college students at their homes by a national college qualifying examination. We have tried this in Iowa far enough to know it will work.

''Our program is to administer this college qualifying examination on the same day throughout the entire United States, to every high-school senior and preparatory-school graduate who may

desire to test himself or herself as to capacity and fitness to do college work. This is an enormous step in advance and it will not only prevent the majority of poor students ever leaving home, but will discover a great many young men and women who have not suspected that they had college ability. A small fee will be charged and since the student takes it for his own information, there is no incentive to cheat.

"You see, boys and girls can thus find out whether they can do college work before they have even declared themselves to friends and neighbors. If they fail once they can study up and try it next year again. Thus the boy and girl who now go off with high hopes of parents and teachers, and perhaps with their names and pictures in the local paper, and who are later forced to return home, will be saved this absurd, unnecessary and discouraging experience. We warn them in time.

"This nation-wide drag-net will also be a great eye-opener to the public on the notion that any one can go to college who wants to or whose parents think that he should go. They will wake up to the fact that it makes a difference. It will enormously advertise what is perhaps the most important discovery of modern psychology, namely, the wide differences among people, and emphasize the equally important fact that these differences can not be readily or entirely overcome by some magic system of education.

"Now, this college qualifying examination does not tell us whether the boy that passes will do best as an engineer, linguist, scientist, mechanic, doctor or what. The next two big steps in our program are *freshman week* and the *placement examinations*.

"I first heard of freshman week at the University of Maine, and at once adopted it as part of my program. It applies readily to every college that has more than two hundred freshmen. During the first three days of the week, the older students are not allowed to return except a few upper-classmen who are honored with an invitation in order to aid the faculty in meeting the new students. These three days are devoted by the faculty and honor students to adjusting the incoming students to their new life. The newcomers are shown all the facilities of the campus, libraries, laboratories, health service, opportunities for earning money, assemblies, churches, recreation and the like. Rooms and boarding places are found with some reference to congeniality. The whole aim is to develop a warm, human, sympathetic substitute for the old welcome that was given to our fathers by the college president who received each boy and girl with a fatherly hand-shake and took a personal interest in getting the newcomers under way.

"The last three days of freshman week are devoted to the third great step in making the college over to fit the student. This step is described by the phrase, *placement examinations*. They are given quietly to the new students off by themselves while the old students are coming back and getting located.

"The placement examination consists of two distinct parts. The first half is the regular examination for testing the student's knowledge of each subject. The second half is something entirely new, and is one of the most significant outcomes of experimental psychology. It consists of a large series of tests designed to measure each student's native aptitude for each subject. It is a great advance over the tests of general intelligence.

"Thus, we test, not a boy's knowledge of English, but his fundamental ability to learn English; we test his mechanical ability, his foreign language ability, his chemistry ability, and so on. We now have thirteen subjects in which aptitude

tests have been developed and we are constantly improving them and adding more.

"The outstanding discovery from these tests has been the astonishing amount by which individuals differ in their capacities, and how permanent these differences are. Your natural capacity to learn English or mathematics or mechanics remains relatively unchanged throughout life. For example, we find in the sense of pitch in music, one person may have one hundred times as great capacity as another, and no amount of training greatly alters this difference between these two persons. Training enables each person to use better what he has but it does not greatly increase his original capacity. This we believe is true of all our original capacities.

"Of course, we must distinguish carefully between what a student can do and what he does do. These aptitude tests measure with encouraging success what he can do. As it is now, where the gifted student and the poor student are placed in the same class, the poor student grows disheartened and the gifted student becomes uninterested, and thus neither measures up to his real capacity.

"The next step goes to the heart of this very situation—probably the most important problem in all education. We call this step 'sectioning on the basis of ability.' It is already extensively in force in many grade and high schools. Our plan is to bring it over with the highest refinements of experimental psychology and apply it to the different kinds of college students. We propose to place the students, and we do place them here, in different classes according to their several abilities as indicated by our aptitude tests.

"In order to see how this works, let us recall what has happened to Johnny and Mary by Saturday night of freshman week. Instead of the old exhaustion and bewilderment, they are by that time all congenially located with reference to dormitories and fraternities; they have met all their instructors and many of the older students, and they have a pretty good idea of what living and learning in college really means.

"But, in addition, our placement examinations with their aptitude tests have put in our hands an entirely new educational instrument of the highest value to each student and to his instructors. This instrument consists in the fact that we not only know each student's training, his home and school record, much about his general traits of character and industry, but we also know his aptitude in each of eight or ten subjects in which he has taken tests. I might remark here in passing, that Dr. Frank Shuttleworth, here at the university, has devised a method for securing a student's home and school record, his character traits, home surroundings and the like, which we believe is going to prove of great value in predicting what a student will do with his aptitudes and abilities—how hard he is probably going to work; and we believe that they also predict with considerable success the general trends of character that he will manifest both in college and in later life.

"You see, therefore, that on Saturday night of freshman week, while both the upper-classmen and the newcomers may be holding the grand democratic social event of the season in which they may all meet and clasp hands in good fellowship, there will be on record a comparatively exact and helpful mental profile of each and every student. This profile furnishes every instructor with a fairly accurate, concrete picture of each student's natural level.

"On this basis, we have found it economical to divide the students into at least three levels—high, average and low. This furnishes a fair starting

place for everybody. Of course, the students are informed that these levels are not absolutely fixed, and that students will be permitted to pass up and down as their further achievements warrant.

"Thus, on Monday morning following freshman week, instead of the old exhaustion, misfit and uncertainty, each instructor is in a position to carry out our motto of keeping each student busy at his highest natural level of successful achievement, because, for the first time, in most colleges, he will know fairly well what each student's natural level of successful achievement is. As a further result, the students, as they greet one another on the campus, say to each other, as we know from our experience here they do say, 'I made the ox-cart,' 'I made the covered wagon,' 'I made the day coach,' 'I made the transcontinental express' or 'I made the aeroplane division.' "

At this point I said to Dean Seashore, "Will not all this give the student who lands in the ox-cart a sense of inferiority and failure?"

"No," replied Dean Seashore firmly. "Our experience has been quite the contrary. It affects a poor student just about the way it affects a financially poor man when he finds out he has no money to invest. He simply doesn't have it and adjusts himself to the fact. Is there any reason why he should not do this? It prevents his trying the impossible. It warns him in time. Moreover, the student is told that this is merely a preliminary sorting out, and he is welcome in the aeroplane division as soon as he demonstrates that he can do the work.

"As a matter of fact, the most gratifying result of sectioning on the basis of ability is that the poor student is not humiliated by being compared with the brilliant student. We find that when students are with their equals all up and down the line, their inequalities, inferiorities and superiorities are forgotten. The good student is put on his mettle to compete with his equals and the poor student is working happily with his equals. I absolutely condemn mixing students of high and low ability in the same class. That is one strong reason why the better students have organized in most colleges to keep from doing their best. In many colleges a brilliant student positively has to conceal his brilliancy. If he does not he is against the gentleman's union and is regarded either as 'showing off,' or as a 'scab.' But with this system, a student must play the game and do his best or else be looked down upon as inferior by his own equals. And no healthy boy or girl can stand that. At least, it is a powerful incentive.

"Moreover, the fellow who is often benefited the most is the bright loafer who lands unexpectedly in the ox-cart, and the jolt wakes him up. Let me give you an example: A boy came here from a military school where he had failed three years in the same course in English. He gave as his alibi that he couldn't learn English.

"I said, 'We'll just find out about that.' So I gave him the aptitude test for English ability, and he made a rank of 84 on a scale of 100, on which the average was 50. But when we tested, not his ability to learn English, but what he had learned of English, he ranked 31 on a scale of 100. So we looked him square in the eye, and said, 'You have been loafing for three years; now you have no alibi.' The boy accepted the challenge and got an 'A' on his first paper in English. His mother had encouraged him to believe he had no English ability, and this feeling was going over into other subjects where he was failing. We doubtless saved that boy from a lifelong sense of inferiority.

"Here is another story that goes to

the heart of some of the biggest problems in American education. I think it illustrates a new doctrine in our national life. We tested a boy and found him to rank in the highest 10 per cent. for ability, but his grades showed that he had loafed all through high school. He soon made it evident that he expected to loaf through college. One day he passed an examination in psychology and the instructor gave him a 'C,' but I marked him 'Failed.' His instructor came to me all wrought up, and said it wasn't fair. I said it was fair to mark him 'Failed,' because he had *failed to do his best*. That was a new doctrine. Shall we hold all students to the same standard, or shall we judge the two-, three- and five-talent students each on his own level? Shall we judge a man by his inferiors or by his peers? Nowadays, if a five-talent student gets a passing grade we pass him, and a two-talent student the same. We thus judge all on about the two-talent average level, a level at which the one-talent boy flunks and the five-talent boy loafs.

"To prove this, I told this instructor that any bright boy could get a 'C' in a generalized subject such as psychology or literature. He said, 'Oh, bosh.' I replied, 'Let's try it.' I got a bright boy in engineering and asked him if he had ever studied psychology. He replied he had not. I then gave him the same examination on which the other student in psychology had gotten a 'C,' and this engineering boy got just as good a 'C' as did the one whom I marked 'Failed.' A bright student can get a passing grade in a number of generalized subjects by merely guessing and drawing on his general information.

"You see, as long as we do not divide the students on the basis of their ability, our present standards for passing are set below the level of mediocrity, so that in a subject where general information counts, a student above the mediocrity level can pass without ever having studied at all! Under this absurd procedure there is no use of his coming to college.

"Now the last step, and the cap sheaf of our whole program is the organization of the junior college—a movement which is rapidly sweeping the country. Just think what it is that the college now says to the boys and girls of this country! It is this: 'Take our whole four years or else you are a college failure.' But the new college will say: 'Take the first two years and try yourself out. If by that time you find the last two years are not suited to your needs, tastes, plans, finances, health and abilities, we will graduate you with a college degree which will always be an honorable emblem of successful achievement, the degree of J.C.G.—Junior College Graduate.'

"Some educators have said that a degree of J.C.G. would not be an honor emblem. But my reply is: 'Look at the graduate of the vocational high school to-day. The parents come out and celebrate, they have a big commencement, and all are proud of the boy or girl. Now, if we simply carry that graduate on to two years of college, and give him or her another diploma, the parents will be prouder still.' "

Here I interrupted Dean Seashore with this question, "But, my dear Dean, can not the colleges do away with their first two years, and turn the junior college over to the present high school?"

"By no means," replied the dean vigorously. "The high schools can not become colleges. The life, program and methods of the high school and the true college are as different as night and day. In fact, the general high-school atmosphere throughout the United States to-day is of a comparatively low order as concerns first, their educational standards; second, their methods of study, and third, their social life. What I propose

in these junior colleges is to take the ambitious students out of that atmosphere and set them a new pace, amid new and more stimulating associations.

"As an example, here are three boys, ambitious for a college education. One has the making of a voucher clerk, one an auto mechanic, and the third, a scientist. They first pass the college qualifying examinations at home, and demonstrate that they are college material. All three then start in the junior college. All are given the same course in English, and each will get a course in biology and also one in mathematics during the first year. The auto mechanic also gets one course in the technical aspects of machines and special work on automobile engines. The bookkeeper gets his special work in accounting—something I would give all college students, as I consider accounting far more cultural, as well as useful, than the classics. The scientist gets extra work in the foundation courses of science. The second year goes on much the same, with more stress laid on the particular work which each student will follow in the future.

"At the end of the two years, the bookkeeper and auto mechanic go home with genuine college diplomas, a genuine liberal culture of recognized standing, instead of being marked as 'eliminants' and 'failures.' The beauty of it is that the two J.C.G. men have gone home with a liberal education. They will carry through life the benefits of two years of college atmosphere, of training under the finest pedagogy and with the highest expert organization of their courses of study.

"You should also grasp clearly that instead of having the cafeteria system of allowing the student to select for himself out of a vast number of electives, as most college freshmen do now, the new junior college will provide a suitable number of elective courses or curricula. From these we will assist each freshman with our placement examinations and by every other means in deciding on the curriculum which will best fit his abilities, temperament, economic and spiritual needs.

"These different courses will have as many elements common to all as is advisable, and they will provide against letting the ignorant student decide, as is done now, whether he shall take physics or chemistry, or whether he shall take chemistry first and physics afterward, or *vice versa*, or whether he shall take German, bookkeeping or civics. We shall decide those fundamental things for him. And while the J.C.G. men will go home as college graduates at the end of two years, the scientist and the academically and professionally minded boy will be encouraged to go on to higher fields of educational achievement and responsibility. For we must never forget that ability to achieve and responsibility for achieving go together.

"I have given you an all too brief résumé of the program for the college of to-morrow. I wish I could tell you about what we term our 'project method' of study. By this method, one professor is able to handle a hundred students or more. Yet he is able to give to each far more individual stimulus and instruction than is given by the present recitation system. I think that this also largely meets the common assumption that a boy gets so much more individual attention and personal contact in the small college. In my judgment, the university with thousands of students can be so organized as to give far more attention to each student's individual needs than was ever possible in the small college. I think also that the small colleges can be more effectively organized to meet the individual needs of each student than they are now. In many studies the recitation system will soon be obsolete. We have better and more

individualized methods already in operation. But I trust I have shown you that the college of to-morrow must, and can, discover, orientate and serve the individual boys and girls far more effectively than it is doing now, or ever has done.

"One thing, at least, is certain, that we shall never have a true science of education until each individual in the entire mass is brought to his highest possible development. This may seem a counsel of perfection, but nevertheless it is the goal of applied psychology and experimental education. For, after all, the science of society, the science of living and the science of education have the same end in view; and I know of no better way to express that common objective than in the maxim of our good student project, 'Keep each individual busy at his highest natural level of successful achievement, in order that he may be happy, useful and good.'"

THE BIRTHPLACE OF MAN

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I. Mesopotamia

Every one, naturally, has a desire to know the birthplace of man. The earliest known writer having this interest was the author of Genesis 2: 8–14. Here an enclosed park or orchard with many kinds of beautiful fruit trees is described. Such parks were common in Babylonia and Assyria where the owners, their families and friends would find great enjoyment since the climate, in these lands, is at times very hot. The Biblical writer, living in Palestine about 850 B. C., locates the park in a territory called Eden situated in the east. The Hebrew word *Eden* means pleasure, delight, loveliness and charm. Some, however, derive Eden from the Assyrian word, *edinu*, meaning plain steppe and prairie. A large river flows from this territory into the park. As it emerges, it branches into four rivers. One of these is called Pishon, encircling the land of Havilah. Another is named Gihon, compassing the land of Cush. The third river is the Hiddekel, or Tigris, flowing in front of Assyria. The fourth is the Euphrates.

In this brief piece of ancient geography the two rivers, Hiddekel or Tigris and Euphrates, are well known. Assyria is very probably the great empire northeast of Babylonia with its capital at Nineveh. Havilah and Cush are doubtful localities, but the former has usually been regarded as Northern Arabia, and the latter as Ethiopia. The two rivers Pishon and Gihon are unknown. No large river is known which is the common source of the Tigris, Euphrates and the two other rivers, Pishon and Gihon. Indeed the Tigris and Euphrates do not spring from a common source. Their nearest sources, in the Taurus mountains, are at least fifty miles apart. The territory, Eden, is also unknown. This indefinite information about the location of the birthplace of man has set scholars to speculating for well-nigh nineteen centuries. Much time, ingenuity and learning have been spent in the search for the exact location of the park in Eden. By actual count over eighty localities have been given as the site of the first home of mankind. These range all the way from the North Pole to Australia. Only a few of them need be mentioned here since a good many are merely wild guesses resting on no secure scholarly foundations.

Josephus, A. D. 37–100, and many church fathers considered the ocean encircling the earth the source of the four rivers. The Pishon was supposed to be the Ganges and the Gihon the Nile. Havilah was India. Eden would then be somewhere in northeastern India. Calumet, A. D. 1672–1757, Rosenmuller, 1768–1835, Keil, 1807–1888, and some other scholars believed the source river was a region of springs. The Pishon and Gihon were mountain streams. The former may have been the Phasis or Araxes, and the latter the Oxus. Eden was located in Armenia. Calvin, 1509–1564, Huet, 1630–1721, and Bochart, 1599–1667, locate Eden in lower Babylonia. The Pishon and Gihon were regarded as channels by which the united rivers, Euphrates and Tigris, entered the Persian Gulf. Luther, 1483–1546, believed that the great flood so altered the course of the rivers as to make it impossible to locate the park in Eden. Several scholars have resorted to allegory. Philo, 20 B. C.–A. D. 40, considered Eden to be the soul delighting in virtue, while

the four rivers were four specific virtues: prudence, temperance, courage and justice. Origen, A. D. 182–251, believed that Eden was heaven and the rivers wisdom.

In modern times several eminent scholars have attacked the problem. Friedrich Delitzsch, 1850–1922, believed that Eden was the Babylonian plain, and that the park was near Babylon. Pishon and Gihon were canals or ancient riverbeds on the west and east sides of the Euphrates. The Pishon would be the Pallacopas, and the Gihon the Shatt en-Nil. Havilah was part of the desert west of the Euphrates. Cush was a name for Babylonia derived from the Kasshites who ruled there as the third dynasty, 1757–1181 B. C. Paul Haupt, 1858–1926, believed that we must not start with the conceptions of modern geography, but with the quite different ideas of geography which the Biblical writer had in mind. Haupt thinks that the narrative in Genesis should be interpreted somewhat as follows. In northern Mesopotamia there was a large body of water suggested by a dim knowledge of the Black Sea. Here was the park in Eden and the sources of the four rivers. The Euphrates and Tigris flowed southward and ended in marshes. The Pishon, suggested by the Kerkha, starting more to the east, flowed into the Persian Gulf, supposed to be a river. It then turned westward encircling Havilah, Arabia, and finally ended in the Red Sea. The Gihon, suggested by the Karun, starting still further east, flowed at first southward and then westward. It encircled Cush, Ethiopia, and finally ended in the Nile.

These differing views show how difficult it is, from the Biblical data, to get an accurate idea of the location of Eden. The Biblical writer probably had in mind some locality in or near Babylonia, in a region watered by a great river, the supposed source of four rivers, Euphrates, Tigris, Pishon and Gihon. It was natural for him to locate the birthplace of man here. Tradition placed the dispersion of mankind in Babylonia where the tower of Babel was erected, Genesis 11: 8–9. Here was the seat of a very ancient civilization. Abraham, the ancestor of the Hebrews, migrated from Ur in Babylonia, Genesis 11: 31. Present-day Old Testament scholars would probably agree in saying that the Biblical writer had only vague and indefinite ideas of geography east of Palestine. He was a spiritual specialist and not a geographical expert. His geography can not be harmonized with our modern exact knowledge of lands and rivers in the Near East. This is not at all surprising, for even Alexander the Great, 356–323 B. C., supposed that he found the sources of the Nile in the Indus because he saw crocodiles and beans there. Pausanias, in the second century A. D., relates the tradition that "the same Nile is the river Euphrates which was lost in a lake and re-emerged as the Nile in the remote part of Ethiopia." L. E. P. Erith correctly sums up the whole matter thus:

> Speculation as to the site of Eden is futile, as may be seen by the discussion in the standard commentaries of the many localities suggested. All that can be said is that the narrative contains reminiscences of the country between the Euphrates and Tigris, and any fertile spot in Mesopotamia may have furnished the basis of the story of the garden.

In recent years important archeological work has been done in Babylonia at such ancient sites as Nippur, Babylon, Ur and Kish. No human remains or artifacts much older than 4000 B. C. have thus far been found. Probably no scholar any longer believes that the birthplace of man was in Mesopotamia.

II. Africa

Some regard Africa as the original home of mankind. As early as 1871 Charles Darwin, in his "Descent of

Man,'' wrote: ''It is somewhat more probable that our early progenitors lived in the African continent than elsewhere.'' More recently, G. Elliot Smith in his ''Essays on the Evolution of Man,'' 1924, favors this continent. He says:

> I call attention to these considerations to suggest that the evidence now at our disposal affords some slight justification for the speculation that Africa may have been the area of characterization, or, to use a more homely phrase, the cradle both of the anthropoid apes and of the human family. In any case it is probable that Africa played an important part in the early history of man and his ancestors.

Two discoveries made a few years ago have also revived this view. In 1921 in Rhodesia, the Rhodes man was found. He is more primitive than the Neanderthal man. In 1924 at Taungs, Bechuanaland, fifty feet below the surface an ape was discovered. Professor Raymond Dart, of Johannesburg University, places it in an intermediate position between man and no-man. The two species of anthropoid apes nearest to man, the gorilla and chimpanzee, are found in Africa. The earliest known remains of anthropoid apes have been unearthed in the Fayum in western Egypt.

A. N. Pond and G. L. Collie, recent explorers in the Sahara Desert, favor Africa as the birthplace of man. So also does Dr. Cadle, who has been exploring the Kalahari desert in South Africa where he found pygmies in Stone Age culture who chattered like baboons and who could count only up to three. The Oriental Institute of Chicago University, under the direction of J. H. Breasted, is engaged in studying the Egyptian Stone Age culture on the Nile. Ancient flints show that the valley was occupied by man about 15000 B. C. Here probably civilization began. By 4000 B. C. the art of communicating by picture writing became well developed. Arts flourished and an organized centralized government appeared in the Nile valley.

III. Europe

Europe has been regarded by some as the cradle of mankind. This opinion has been held for two main reasons. Very many skeletal remains of prehistoric man have been found in Europe. The Heidelberg, Piltdown, Neanderthal and Cro-Magnon remains were all discovered on this continent. Then, too, very many artifacts have been unearthed in Europe. These consist of weapons, tools, implements, utensils, pottery, paintings and sculpture. Among the scholars who regard Europe as the birthplace of man is A. Hrdlička, who says: ''The cradle of the human race was western and southwestern Europe.''

IV. Asia

In recent years numbers of scholars have come to believe that central Asia has the best claim to be the earliest home of mankind. There are ten main reasons for this view. (1) The oldest human remains, the Java man, were found on the island of Java which was once a part of the mainland of Asia. (2) In 1921 in a cave southwest of Peking a premolar and molar tooth were found. These go back to the early Quaternary age. (3) Artifacts, the handiwork of prehistoric man of not later than 25000 B. C., have been found in Mongolia by Roy Chapman Andrews. (4) Sand-drifted ruins of a very great age have been found in Mongolia. These, while not yet explored, are supposed to represent a very ancient civilization. (5) Two species of anthropoids have been discovered in Asia. These are the orangs and gibbons. (6) Remains of Primates, the highest order of mammals, either ancestral or closely related to the living anthropoids have been unearthed on this continent. (7) Most of our domestic animals and cereals have come from Asia. (8) Mongolia is the oldest dry land on the globe. It has been dry twenty million of years, while other parts of the earth have been submerged. (9) The great size of Asia,

with varying life conditions, would be favorable for the development of primitive man. (10) Asia is located centrally to other lands. Migrations going north, south, east and west could easily start from here.

Among the scholars locating the birthplace of man in Asia the following may be mentioned. S. W. Williston, says:[1] "Man was born and attained elemental civilization in Asia because there was the place of all others upon the earth where evolution, in general, of organic life reached its highest development in late Cenozoic times." H. F. Osborn writes:[2] "The unknown ancestors of man probably originated among the forests and food plains of southern Asia and early began to migrate westward into northern Africa and western Europe." J. M. Tyler[3] remarks: "But the climatic conditions of that time lead us to seek his original cradle somewhat further northward than India or even Beluchistan, and nearer to, if not in the great steppe zone of central Asia." E. G. Conklin says:[4] "From his earliest home, probably in the table-lands of Central Asia, successive waves of human migration have flowed forth in all directions." R. S. Lull observes:[5] "That Asia is the birthplace of mankind is seemingly established." J. A. Thomson writes:[6] "The possibility is that the cradle of the human race was in Asia." W. H. Worrell says:[7] "On the whole it appears most likely that man first appeared somewhere in Asia." It is expected that the explorations of Roy Chapman Andrews in Mongolia will confirm the Asiatic origin of man.

[1] *Pop. Science Monthly*, 1910.

[2] "Men of Old Stone Age," 1918.

[3] "New Stone Age in Northern Europe," 1921.

[4] "Direction of Human Evolution," 1921.

[5] "Evolution of Man," 1922.

[6] "Outlines of Science," 1922.

[7] "Races in Ancient Near East," 1927.

THE PEACEFUL PENETRATION OF ATOMISM

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As the mass of facts and opinions available in the field of science grows at its present enormous rate, it becomes increasingly difficult to exercise that subtle discrimination by which we are often kept in the right path of progress. It becomes increasingly difficult to avoid blind alleys. This is realized by our more mature and successful colleagues, and tempts them to map out the path which must be pursued in the future. Much of this is of the greatest value, while on the other hand some of it comes from fatigued workers whose courage and insight are at a low ebb. In many instances the necessity of taking the suggestion *cum grano salis* is obvious; in others it is not. Moreover, the map supplied is sometimes accompanied by a commentary, stating that certain courses must under no circumstances be entered upon because these lead to chaos. In other words, the straight and narrow path is pointed out with the warning that the other "goes to the devil." In this way the research worker is led to fear heresy and his colleagues to punish him as a heretic if he insists upon pursuing his "evil" ways. Now "going to the devil" in the eyes of friends and colleagues has always been one of the unique privileges of a creative mind, and it would be unkind to minimize the hazards in this respect. However, there are certain heresies of this sort that ought to be discussed from time to time, because the fact that they are merely heresies and not errors is not altogether obvious.

Recently the writer has heard and read a number of warnings against atomism in biological thought. This is alleged to be a line of approach to the problems of life which is bound to fail—any other attack is to be preferred to the chaos that would result from such an approach. In justice to the commentators referred to, it ought to be admitted, in the beginning, that all of them were right when judged from the standpoint of their own view and vision of atomism; and this essay is justified as an attempt to achieve a more adequate conception of atomism, not so much on the basis of what it has been, but upon what it now appears to be.

For our purposes, we may define atomism as a conception that the universe is built up of discrete units. Such a view would be the opposite of that which considers the units in themselves as nothing —the whole is all that there is.

Without attempting to justify either of these views or to elaborate upon the suggested polarity of view-point, let us consider the atomistic conception and its contributions, since this is the approach that we so frequently misunderstand, and is the exceptional, rather than the common view of things.

Just who first adopted the atomistic way of thinking will never be known. We know to a certainty that cultured men have discussed the matter since ancient times. Thus the differences in the nature and qualities of emeralds, pearls and diamonds may well have been a subject of polite conversation in those days. Surely, on some such occasion a prophet ventured the statement that only by taking these gems apart could their true nature and the basis of their differences be determined. No doubt he was laughed out of court, and told that one might as well think that one could determine something of importance about a fine painting or fresco by discovering the nature of the pigments and

the vehicle used in the paint. This view held the field, for the main part, until about one hundred and fifty years ago. By that time the chemist had perfected his tools sufficiently to attack the problems effectively. The story of the solution is well known and need not be reviewed. The atomist has pursued his way until he is now equipped to attack successfully all problems relating to the atomic constitution and nature of things. Moreover, he has taken his atoms, formerly indivisible (by definition), and by subdivision has achieved the potent electron—the electrical atom. In so doing, he has brought his dead atom to "life," to his own astonishment. Then, in order to visualize the relations and behavior of this "living" atom, he has had to borrow concepts and methods from the great field of atomism—namely, astronomy. When these atomic physicists and astronomers get through with the chemist's dead atom, it will be a strange and wonderful "creature."

Now it is a surprising thing that some of our modern prophets wish to caution us against visualizing any possible intermediate realms of atomism developed on scales larger than the inconceivably small astronomical systems of the atomic physicist and smaller than the inconceivably large "atomic" systems of the astronomer. Such an attitude takes no account of the possibility that these two realms are the two ends of "the same stick," and that possibly the path that we are warned against is the obvious one for us to explore. Fortunately, perhaps, the warning comes too late. The atomic "horse" has already been stolen and used with effective power by biologists in several ways.

The whole history of morphology illustrates on the one hand the reluctance of the biologist to have recourse to "atomic" concepts, and on the other the marvelous illumination that has followed their use. Eventually, however, the cell doctrine was achieved by the biologist, and in spite of the disadvantages of seeing so little of his problem at one time he has made enormous progress with it. This progress has been accelerated more and more as the focus has been sharpened and the conceptual magnification increased. For instance, the problem of sexual reproduction is one of atomism. First, we had the microscopic sex elements. The novice shown a giant oak and then a grain of pollen from a blossom might easily find the suggestion ridiculous that such a minute bit of yellow dust could play any significant rôle in the life of a great tree. But biological atomism has gone very much farther. This atom of the oak has been subdivided until the grain of pollen becomes a complex system of smaller units, some of which actually determine the species characters of the future oak-tree.

Bacteriology in its various branches has developed its own atomism. Perhaps the original indivisible atom was in this case the bacillus, but as in the case of the chemical atom this is apparently undergoing subdivision and is breaking down as a limiting concept. We have the filtrable viruses and bacteriophage as possible subdivisions of the bacillus. In fact, the whole trend and the tendency of the recent history of the cell, the biologist's "atom," is in the direction of further subdivision, in which respect its fate is analogous to that of the chemist's atom.

We might elaborate the discussion of atomistic conceptions in biology, but the above is sufficient to indicate the importance and fruitfulness of the view-point in the last fifty or sixty years. Probably these developments are not directly due to chemistry, but surely the workers in these sciences have not failed to obtain encouragement from the success of the chemist in his simpler field and problems. In fact, some of the fundamental advances were made by chemists working

in these fields with their well-tried and proven chemical technique of thought and work.

At just about this point, some one will wish to interject that the use of the term atomism in relation to morphology is, after all, based on analogy. The chemist has isolated his chemical elements, while the elements of the morphologist have never been isolated. In all fairness, we must admit that the geneticists have gone farther in the isolation of their "elements" than any one could have dreamed they would twenty years ago, and that the word "isolation" in this connection is used in a somewhat different sense than that in which it is usually employed by the chemist. The chief objection does not, however, arise in this connection. It actually arises from the fact that there is no known intermediate step between the field of these living biological elements and that of the true chemical elements. Since this is the range in which we pass from the animate to the inanimate, in our usual way of thinking, it constitutes an important step. As we have seen, the biologist started from the consideration of gross units, and is moving toward the fine; the chemist started his attack from the fine, and is moving toward the gross, as in the field of colloid chemistry, and they have not yet gotten close enough to join hands and forces to the best mutual advantage. Where will this union of forces occur, and what problem may it be expected to solve? To answer such a question is perhaps unwise, but if the attempted answer is stimulating, it will have served a useful purpose.

It takes no especially profound insight to see that this union will occur in the field of the chemistry and biology of protoplasm and more specifically largely in the field of proteins, for reasons which may be briefly reviewed.

Under the conditions existing on the earth, carbon and hydrogen form many compounds. If we add oxygen to the pair, the number is enormously increased. If we add a few other elements to the list and consider all known combinations, the organic chemist will show us a series of several hundred thousand, and admits that he has no idea how many more he might obtain. Some of these compounds are proteins, and some of the proteins are water-soluble albumins. Although albumins from various sources appear to be very nearly alike chemically, yet results of biological tests give basis for the belief that perhaps every species of plant and animal has its own specific albumins. The idea of similarity and identity arises only from the use of an inadequate method. The chemist is in this case driven to admit that so far as an eventual understanding of the nature of the species specificity of proteins is concerned, he has made about the same relative degree of progress that the ancients had made when they spoke of their four elements, one of which was "earth." As we know, "earth" has now resolved itself into about ninety individual elements, and we know a great deal about how these are combined to make "earth." Zealous pursuit of the atomistic conception brought us to where we are at present in this field. The same type of attack has, however, so far failed to enable us to solve the protein problem. We know the nature of the chemical elements, of the chemical groups, of the chemical units or building-stones and many other facts about proteins, but all the things that we know tend to make us emphasize their similarities—they are all "earth." The true atomicity of these compounds, if they are to be viewed in this way, therefore involves something that is unknown, or at least is not associated with proteins in our thinking.

That this unknown factor, whatever it is, lies at the very basis of life itself is clear to every one who has thought of it. Along with water, proteins are quanti-

tatively the most important factor in the chemical basis of life. The three main organic components of the cell are proteins, carbohydrates and fats. The carbohydrates are, aside from their elaboration into chemically inert systems for skeletal support in plants, the fuel of the organism, *par excellence*. The true fats are essentially food reserves, and so not primarily concerned. This leaves the proteins as the quantitatively important protoplasmic components which constitute the foundation structure for life, the activities of which are essentially conditioned by water and modified by a host of other components of no quantitative importance, but which qualitatively have a very great importance, the limits of which are at present unknown. May we, therefore, not say that the proteins are the chemical atoms of life, and just as the nature of earths is determined by the chemical elements of which they are composed, so the nature of the organism is determined in some important part by the characters of its proteins. That is, organisms are composed of "atoms" of a higher order than the atoms and simple molecules of the chemist that are usually considered. The chemist's failure to interpret life, therefore, arises from his attempt to use a lower order of atoms and molecules as his units. Such "biochemical atoms" have nothing in common with the chemical atoms when considered in one way, and have everything in common with them when considered in another way.

The idea that there is another world within the range of dimensions under consideration is not new. It is suggested by the arresting title of one of Wo. Ostwald's books, "Die Welt der vernachlässigten Dimensionen." By incorporating the idea of the neglected dimensions, Ostwald tried to drive home the fact that between the realm of molecular dimensions and that of microscopic dimensions there is a whole world of phenomena usually called colloid chemistry. It is in this realm that the preparatory work is being done which will possibly lead to the definition, at least, of the biochemical elements of life, and possibly eventually at some future time to their isolation and synthesis. We are still in the alchemistic stage of this chemistry; our interest is chiefly the transmutation of base metals into gold, *i.e.*, corn into hog fat and pork chops, and the search for the philosopher's stone, *i.e.*, condiments and cosmetics, anesthetics and aniline dyes. When our quest becomes unselfish, we will step out of the alchemistic period into the modern period of this chemistry.

Although we can not define these biochemical elements, we can perhaps see something of how they will appear in general. In atomic chemistry, our atoms may lose or gain one or a few electrons, and in either case, they become chemically active, *i.e.*, alive. Chemical death is persistent retention of just the right number of electrons. When atoms combine, presumably the attractions are satisfied, but if they remain so in all cases, we again have chemical death. When molecules or radicals have more or less than their quota of energy, even momentarily, they become chemically active. Without elaborating this in further detail, it is obvious that every atomic system, on whatever scale it is conceived, will have properties of this sort, and consequently one of the recognition signs of an "atomic system" will be this momentary lability or unsaturation.

This hypothetical discussion may be summarized by saying that even now chemical data are falling into order in such a way as to justify the suggestion that the "biochemical elements" of life will be found in the range of colloidal phenomena, and that if they actually exist they will have a complexity of this order.

Filling out the atomic scale beyond the range of the morphologist's units of cells and on into the higher ranges will not require so much imagination, but rather a fine sense of discrimination. For instance, an individual human being is a social atom. Polarity in the first instance arises with sex. One man and one woman, given suitable affinity, constitute the most stable, self-contained, social molecule. Two of one and one of the other may develop instabilities not manifest in the simple binary unit. In fact, all the characteristic processes of chemistry can be readily represented and elucidated by the use of human relations, including positive and negative as well as primary and secondary catalysis, autocatalysis, etc. These societies are in turn the atoms of larger units. Moreover, it is clear from the biology of insects, and of man especially, that this building up of more and more complex units is an essential part of the evolutionary process. So, just as there is a periodic law of the chemical elements in which similar properties recur in a somewhat different form, associated with a more complex atomic structure, so in nature as a whole there is a comprehensive periodic law, of which that of the chemical elements is perhaps only the initial stage. Similarly, just as the stability of a chemical atom decreases when the complexity of the positive nucleus reaches certain ranges under conditions that we know, so the biochemical elements of various orders reach limiting values. Thus, since surface increases as the square, while volume increases as the cube, and since all cellular supplies and wastes must pass through the surface, the relation of surface to volume will show optima for every range of biological units. Thus, the yeast cell, the sponge, the elephant and the whale have met this problem, each in his own way, by developing its own "atomic" structure, its own organization. This organization is usually not evident except in synthetic organisms like an army. Here trial and error has developed efficiency in building up the "atomic" units in which the various problems of the existence and the functions of an army as a unified organism are solved. The same principle will hold true for a leaf or a city. There must be an optimum size for leaves under given conditions in which the movements of the sap are balanced against the loss of water by evaporation, for instance. In the case of cities, the problems of procuring supplies and removing wastes develop as limiting factors, not to mention other problems such as that of internal movement. Thus, Chicago is confronted with an immense sewage problem, while Los Angeles finds an adequate water supply an acute question, and New York is seriously limited in horizontal growth.

Many other examples might be cited, but these are enough to indicate that very likely the size of atoms in general is determined by mechano-geometrical considerations just as it appears to be in the chemical atom. In all cases, many factors are involved in determining the size of the unit, and it would be unwise to attempt to define them closely in any particular case at the present time.

From all the above, it is becoming clear that the problem of philosophy and of science at present is accordingly not that of restricting the use of the atomistic conception, but of broadening it into a more powerful tool in the development of more adequate conceptual models of things in general. Probably every worker who has yielded himself to the atomistic conception of things did so with a secret dread that he was going to lose something precious, but found himself in the end enriched and better able to visualize and understand the unit which he had dissected. Moreover, hav-

ing familiarised himself with the components, he is better able to understand that the unit is more than the sum of its parts. Thus, a physiologically normal salt solution is more than the sum of the salt and water of which it is composed. In general, even within the range of the so-called homogeneous systems of chemistry, the more complex a system is, the more properties it possesses and the more subtle some of them are even to the point of being indescribable and immeasurable. When we pass into the range of heterogeneous and colloidal systems, this becomes even more true. Consequently, it is easy to see why every thoughtful worker preoccupied with atomistic concepts is never unaware of the so-called "Gestalt" concept. He realizes that his atoms, whatever their scale, are composed of simpler atoms, and in turn constitute parts of larger, more complex atoms, and that any account that he gives of the atomic system in which he is interested at the moment is incomplete. In fact, the atomist is the only worker who is trained and equipped to understand the statement that the properties of a unit are never merely the algebraic sum of the properties of its component parts, regardless of the scale upon which these are defined. The properties of water are not merely the algebraic sum of those of hydrogen and oxygen. A man is more than the sum of the chemical substances of which he is composed or than the sum of his individual organs and tissues.

If we revert to the illustrations used in the introduction, it appears that the chemist, who by long experience has learned something about carbon, is better prepared to appreciate the beautiful crystal architecture of the diamond. His knowledge of carbon prepares him to appreciate the greater mysteries of the emerald and the pearl. The paint chemist knows just where the technical mastery of paint manufacture stops and the skill of the artist begins.

The danger that we appear to face in science, then, is not that of too much atomism, but rather that of not enough. Atomism has been a tremendously powerful intellectual tool in the conquest of our environment, but its successes have consisted in two steps—analysis and synthesis. If we stop at analysis, we are lost, and probably the warnings of our prophets were really directed against this—the error of going only half way through. But here again, the classical method of chemistry should help us. According to this method a problem is not solved until the analysis has been confirmed by the synthesis. This, after all, must be the final test of all atomistic conceptions—analysis followed by synthesis.

Finally, the writer is bound to say that if the reader has read this far and is not reduced to a state of profound humility at the sight of the work that remains to be accomplished, and at the same time inspired by a sense of power and courage at the comprehensive vision of what has already been done, then he has failed to follow the spirit of this essay. We stand as children with Newton on the shore of the sea of time and space, picking up a pretty shell or bit of coral here and there, but we are permitted to have the consciousness that the trifle that we have in hand bears some integral relation to the ocean of truth which lies beyond.

THE CHEMISTRY OF THE FORMATION OF POISONS IN PLANTS

By Lieutenant ROBERT E. SADTLER

MANY poisonous alkaloids, glucosides, toxins, toxalbumins and saponins occur in various species of plants. There are other chemical substances found in plants which are not strongly toxic but curative in their properties. Both classes of substances are products of plant metabolism or serve as reserve food substances. For example, hydrocyanic acid is regarded as the first product of nitrogen assimilation in the plant. These poisons also have a marked protective function to the plant. Many poisons occur in the insoluble form in the cell-sap, as morphin, atropin, digitalin, veratrin and muscarin, without injury to the plant. The physiological effect of various poisons upon different species of plants is variable, due to the variations in the constituency of the protoplasm of the plants. An alkaloid may act as a stimulant upon one plant and have a distinct toxic effect upon another plant of different species.

The toxic substance may occur only in the seed of the plant, and after germination the poison may be decomposed. In certain other plants, the earlier stages are non-toxic, but when it reaches maturity the poison is formed in the latex. This is the usual process in the formation of narcotic substances. In other cases, the poison is formed by the reaction due to the contact between two different tissues or parts of the same plant. Hydrocyanic acid is formed in this manner from the glucoside, amygdalin, by contact with an enzyme emulsion. Amygdalin occurs in the leaves of the cherry-laurel, and in the bitter almond.

The chemical activity of the individual vegetable poison is largely dependent upon the age of the plant producing it. The poison may be found in many different parts of the plant, as the stem, flowers, root, fruit, leaves or seed. Usually the poison found in aerial parts of plants is more transient than poison found in stem or roots. In certain cases, only the subterranean part of the plant is poisonous, as in the common European violet. Or the poison may be produced solely by the action of light, upon the subterranean part of the plant. An illustration of this is the green tuber of the potato.

Poisons are elaborated equally well both in deciduous and evergreen leaves. A thorough study of their relative toxicity, however, has never been made. The production of poison in plants is also dependent upon the following environmental factors: heat, light, season, soil, climate, fertility and culture. And of these factors, season, climate and cultivation, without question, play the greatest part in the formation of poison in plants.

Heat, when prolonged, causes dessication of the plant, evaporation of vital plant juices and volatilization of some of the poisons.

Light retards the growth of parasitic fungi and bacteria. Light also renders certain species of pathogenic bacteria quite innocuous. Certain poisons are formed only in the presence of light, and others only in darkness. Solanin ($C_{42}H_{75}NO_2$), a poison obtained from solanaceous plants, is produced only in the presence of light. Atractylin is another poisonous alkaloid produced only in darkness.

The amount of poison contained in the leaf and stem of a plant varies with the advance of the season. In some

plants, the poison passes from the leaves and becomes concentrated in the seed. Experimental work has shown that some plants are less toxic in summer than they are in fall, winter and spring. Plants which illustrate this principle are cowbane (*Cicuta maculata*), and musquash-root (*Cicuta vagana*). The fact has also been definitely established that plants lose much of their toxicity as they approach the flowering stage. The largest amount of acrid toxic substance is concentrated in the plant in spring. This has been shown by experiments with the opium plant and larkspur. However, there are some plants such as the mountain laurel which are most toxic in winter.

The content of hydrocyanic acid in plants also varies with the seasons. Experiments with the plane-tree have shown that the hydrocyanic acid content is greatest in young leaves. Experiments with other plants indicate also that as the poison becomes concentrated in the pod, the leaves become less toxic.

The exact part played by soil in the formation of the poisonous constituents of plants has not been fully determined. It is known that calcareous soils affect the color of certain poisonous plants and decrease their toxicity.

Climate has a significant influence upon plants, for example, cherry-laurel and aconite, which are poisonous in temperate regions, lose their toxicity when taken into colder regions. More poisonous species of plants are found in tropical regions than in colder zones, largely because of the heat and humidity.

The relative humidity of climatic zones affects the quantity and quality of vegetable poisons produced in the plant. Dry climates produce a greater amount of glucoside which can be converted into hydrocyanic acid (by hydrolysis) than moist regions. For example, the amount of alkaloid in the cola-nut varies with the climatic zone. The superior quality of certain kinds of opium is attributed to climatic conditions. These conditions also affect the amount of nicotin found in tobacco. The percentage of nicotin in tobacco varies from one half of 1 per cent. to 8.8 per cent., largely dependent upon soil and climatic conditions. Other chemical products of plants vary with climatic conditions also to a considerable degree.

Poisonous plants are usually very fertile. Culture of poisonous plants may eliminate the poisonous substance from the plant. Illustrations of this fact are seen in wild vetch and aconite, which when cultivated lose most of their toxic properties. Also certain forms of toxic bacteria, *e.g.*, *Streptococcus pyogenes*, lose their pathogenic properties when cultivated. However, there are many plants which retain their toxicity although they have been extensively cultivated for centuries.

Toxic substances usually have a wide distribution in related species of plants. For example, hydrocyanic acid varies from 2.2 per cent. in the kernels of fresh peach to 4.8 per cent. in the bitter almond.

There is also a wide distribution of toxic substances in plants that are not phylogenetically related. The irritant, glucoside poison, saponin ($C_{32}H_{54}P_{18}$), occurs in many different plants with widely varying botanical characteristics as quillaia and soap-wort.

Some of the most important families of plants having species which contain saponin are: Rutaceae, Sapotaceae, Saxifragaceae, Simarubaceae, Solanaceae, Tiliaceae, Araceae, Begoniaceae, Berberidaceae, Caryophyllaceae, Compositae (Arnica), Convolvulaceae, Dioscoreaceae, Euphorbiaceae, Filices, Graminae, Hippocastanaceae, Leguminoseae, Liliaceae, Loganeaceae, Myrtaceae, Oleaceae, Passifloraceae, Polemoniaceae, Polygalaceae, Primulaceae, Ranunculaceae, Roseaceae, and Rubiaceae.

The most important families of plants

containing glucosides yielding hydrocyanic acid are: Gramineae, Compositae (Briza, salt grass, wild rye, etc.), Ranunculaceae, Filices, Euphorbiaceae, and Saxifrage family. Of this last family, the most toxic plant is Jamesia or Rocky Mountain shrub.

One of the most important classes of vegetable poisons—the toxalbumins—are produced by the action of bacteria and fungi. Some of the most important of these poisons are found in the plant juices, as phallin, abrin and ricin, which occurs in castor-oil seed. Black locust is another important type of toxalbuminic poison.

The purpose of this paper has been to summarize the factors which produce poison in plants, and to state briefly some of the general principles of vegetable poison formation. I have also referred briefly to several poisons produced by bacterial action, and named some of the plant families in which certain specific poisons, like hydrocyanic acid, occur.

STUDENT HEALTH SERVICES AND MODERN MEDICINE

By Dr. J. HOWARD BEARD

UNIVERSITY OF ILLINOIS

THE progress of modern medicine is determined by three factors: a sufficient number of well-trained physicians, fruitful research and a public who appreciates the possibilities of medicine to serve it. The greatest of these three is an intelligent public, sympathetic with the medical profession and ready to give public health administration the necessary moral and financial support to make it commensurate with scientific knowledge.

MEDICAL TRAINING

There are approximately 149,521 doctors in continental United States, which is one physician to every 793 persons in the population. The total deaths in the profession during 1927 was 2,790. The number of graduates of medical schools for the year ending June 30, 1928, was 4,262, which, without allowing for the failure of the two periods to coincide, is a net gain of 1,472 doctors for the year.

In spite of the requirement of high-school graduation, two years' college education, four years' professional training and a year's internship to be eligible to practice, the number of students entering medical schools since 1919 has shown an increase of about 1,000 per annum. As only 17 per cent. of those matriculating fail to graduate, the steady increase in the number receiving the M.D. degree not only insures a replacement of the physicians who die or become inactive but it also provides for the annual addition to the population.

There is no shortage in physicians for the country as a whole, but there are certain irregularities in their location that are due to the social, educational, economic and professional advantages associated with density of population, rapid transportation and with the need of hospital and laboratory facilities in the practice of modern medicine. The rapid increase in the mileage of improved roads is making the town and country mutually more accessible and is doing much to relieve the rural sections of the disadvantages due to unequal distribution of doctors.

The above considerations are presented to emphasize the fact that, whatever its handicaps, modern medicine is not likely to be retarded in its progress

by the lack of a sufficient number of highly trained physicians to practice it.

Productive Research

The epochal contributions to medicine during the last fifty years prove that medical progress has not been seriously impeded by the want of discovery during the last five decades. Medical knowledge has increased more in the period from Pasteur to Banting than from the beginning of the practice of medicine by ancient priests to 1870. Research has been overwhelmingly prolific and its results revolutionary. The profession has been swamped with facts and technique until in self-defense its members have been compelled to limit their activities to escape superficiality and to make it possible to exploit adequately a particular field.

In brief, this is the story of the creation of the hundred and one specialties of medicine. Likewise, it is the history of productive investigation at the bedside, in the clinic, in the laboratory and in the great institutes of research. To-day, discovery follows discovery with such rapidity that there appears to be no decrease in the fertility of research. There is no indication that medical progress will halt because of the failure of scientific investigation to mine new facts.

The Perplexity of the Public

If the profession has had to narrow its front to increase its depth and strength, what is the perplexity of the average layman when he contemplates medicine in its relation to himself, his family and his community? If it is true that the average citizen's knowledge of medicine is on the average three generations behind the profession, how out of date must be his medical conceptions when medicine has acquired more facts in the last five decades than in the previous five thousand years?

In the disparity between scientific knowledge and public information is found the explanation for such acts as that of a graduate of two universities putting a fly blister on his elbow to keep influenza out of his mouth, and that of the painter with a fourth-grade education on a city council defeating a model milk ordinance endorsed by the local medical profession, the surgeons-general of the army and U. S. Public Health Service and by the director of the State Department of Health. It also explains the reason for an outstanding financier glazing his home with costly special glass to protect his children against rickets when two minutes out of doors would be worth fifteen hours inside the house fifteen feet from the window.

It should cause no surprise when individuals otherwise known for their excellent judgment are found worshiping at the shrines of pseudoscience and unscientific medicine. Current periodicals portray the virtues of glorified antiseptics, the miracles wrought by yeast, the wonders accomplished by artificial light, the preposterous claims of the latest proprietary, food or fad, and by no means least the sylph-like beauty to be derived by maidens reaching for a cigarette instead of a sweet.

In such advertisements the truth is twisted cleverly to trap both the ignorant and the gullible. Such health appeals block the progress of medicine by filling the layman's mind with medical "bunk" and scientific "hooey." Neither medical training nor research can meet such a situation. Education alone is the solution.

The public is becoming more and more enmeshed by cults, "-isms," "-pathies" and therapies. In the year 1929, voodooism is reported to be wide-spread in some of the most prosperous counties of one of the oldest and most enlightened states of the union. Even murder is committed by its exponents to get a lock

of hair to bury eight feet underground to break a "spell."

Quackery has never been so high-powered, more able to deceive the average individual, more costly than to-day. The great developments of science in the last few decades afford it so many chances for new disguise in apparatus, method and formula that it has not only become a menace to health and the progress of medicine, but it takes millions of dollars annually from those least able to part with their money.

Though the truth is said always to triumph, the odds favor quackery. While a scientific fact is singular, fraud built about it may be multiple. It is easier to educate to buy than to teach to understand. Besides, mankind in general seems more resistant to truth than humbuggery. As medicine becomes more technical by the greater application of biology, physics and chemistry to diagnose, control and treat disease, only the searching rays of knowledge can save the public from the pseudoscience of the mountebank.

The Magnitude of the Task of Medicine

The mission of medicine is not only the alleviation of human suffering but it has the more sacred duty of promoting a national vitality and intelligence which shall make the nation immune to the forces of degeneracy and retrogression which laid waste the empires of the past. As Laycock has pointed out, man as compared with other animals is peculiarly predisposed to degeneration of the nervous system, and civilized man more so than his uncivilized brother. For this reason and for the fact that, with painful regularity, nations have risen only to decay, certain observers have seen in civilization the symptoms of disease whose end is national dissolution. If such views are correct, modern medicine has a challenge which will tax its every resource.

There are no more undiscovered continents in which civilization may be revitalized by pioneers developing a new life in a new world. The rejuvenation of nations by incursions of a more vigorous primitive people becomes unlikely with the greater development of communication, the intermixture of customs and world-wide recognition of national boundaries. As the center of population moves farther and farther into the city and rapid transportation makes the rural sections increasingly the suburbs of a metropolis, the countryside correspondingly loses its value as a producer of a bold peasantry able to give renewed vigor, "Where wealth accumulates and men decay."

National vigor must depend more and more upon the taking of thought. Man faces the issues squarely of whether or not he is capable of employing scientific knowledge in time and thoroughly enough to produce racial betterment, to insure each of his fellows sanitary living conditions and to obtain the health which qualifies him to live most and serve best.

While research has thrust upon two generations a mass of facts concerning heredity, the processes and development of life, the interrelationships of species and the possibility of advancing human welfare, greater than man has known since Adam left Eden, parallel development in the mechanical arts, in the use of electrical energy, in the application of chemistry and in transportation makes this extraordinary advancement only relative rather than phenomenal.

Two health problems have been produced for each one that industrialism and engineering have furnished the means of solving. Needs arise and opportunity knocks, but generations pass before the one is met and the other heard. If to this situation is added the usual long latent period between the acquisition of knowledge and its general use by the public, it is clear that modern

medicine faces a gigantic task in making its performance commensurate with its possibility.

The Trend of the Health Movement

From isolation practiced by the ancient Hebrews and later legalized as quarantine by the Venetians, preventive medicine entered an era of sanitation. From an epoch of "clean-up," it has become intimately personal. Therefore, its future depends upon the success of making every intelligent citizen an active public health worker, otherwise majority action to obtain individual benefit is impossible.

To-day the periodic physical examination and health education are declared to be the most hopeful means by which modern medicine can further increase the average expectancy of life, promote physical efficiency and insure national vitality. If such are to be its weapons in a new day to meet new conditions, there is no agency anywhere in a more strategic position to serve the public and to advance the progress of medicine than a student health service in an institution of higher learning. In their ability to serve society is the secret of the phenomenal development of these departments in universities, colleges and normal schools.

Student Health Services

A student health service is a health center within an institution of higher learning. It is dedicated to the conception that constructive dynamic living, in the best environment that modern science can provide, is the rightful inheritance of every individual. To attain this ideal it teaches the student the principles of hygiene and sanitation as they relate to him, to his home, to his vocation and to his community. Its methods are classroom instruction, the periodic physical examination, the personal conference, demonstration of disease control and the maintenance of sanitary surroundings. It strives to reveal to the leader of to-morrow the benefits to be derived from hospitalization, public health and modern medicine, because such knowledge will mean much to him, to his family, to his community, to diagnosis, to treatment, to the equipment and maintenance of hospitals and to national vigor.

It is the purpose of health services neither to pauperize nor paternalize students nor to socialize medicine, but to put the college graduate and the physician shoulder to shoulder to mutual advantage in serving society, in advancing scientific medicine and in making a better world.

THE PROGRESS OF SCIENCE

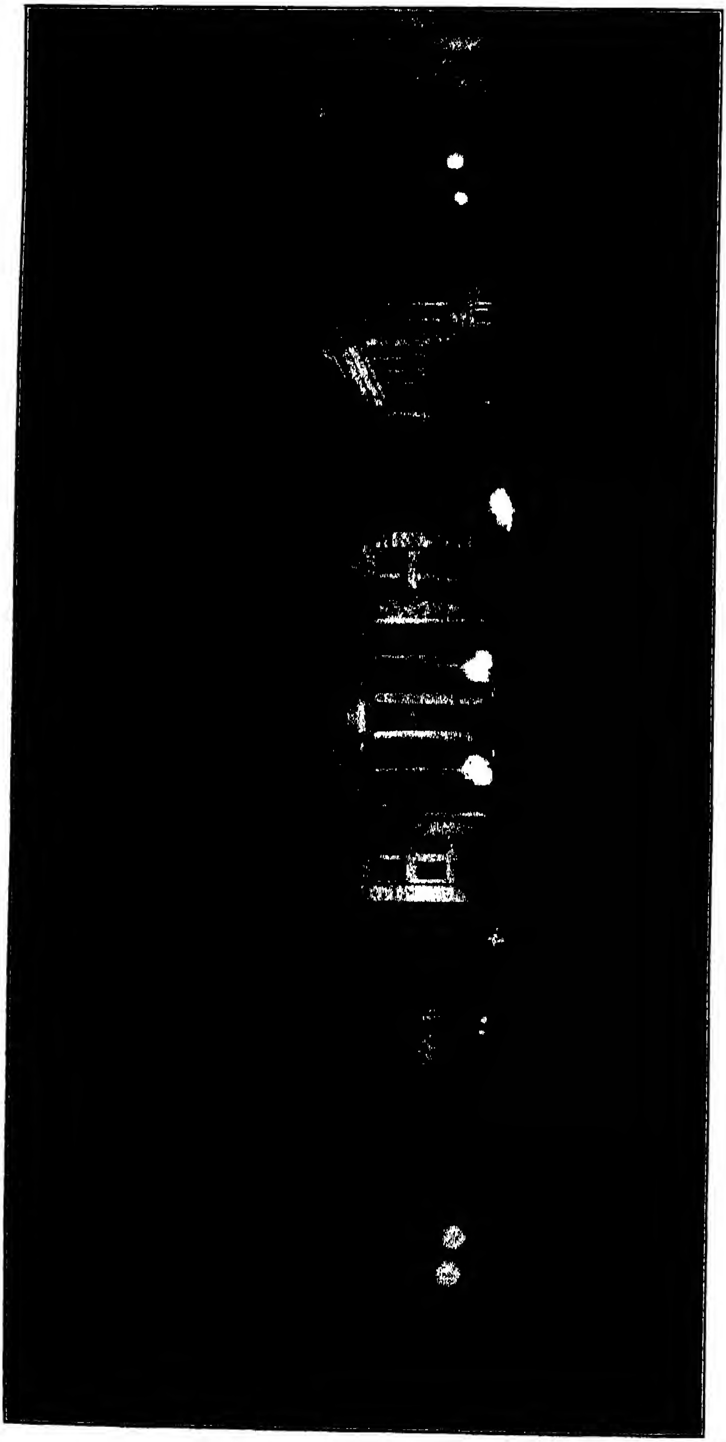
THE THIRTEENTH INTERNATIONAL PHYSIOLOGICAL CONGRESS AT HARVARD UNIVERSITY

INTERNATIONAL scientific congresses met but rarely in the United States before the war. Since the resumption of international relations there have been congresses of botany, agriculture and entomology; now congresses of physiology and psychology have been held here, the former at Harvard, the latter at Yale. These congresses were successful beyond expectation, most of all in the attendance from abroad, although the number of American members and the number of papers presented by them are also noteworthy. This is fortunate, for as one of the speakers is reported in the daily press to have said: "International congresses are significant factors in the advancement of scientific research; they also promote international cooperation and good-will. The objects of the sciences are more ideal than the objects of the churches; their practices are more Christian. When in the fulness of time there is a family of the nations, when each will give according to its ability and receive according to its needs, when war among them will be as absurd as it would now be for members of this congress to begin murdering one another, this will be due in no small measure to cooperation among scientific men of all nations in their common work."

The number of members registered at the Physiological Congress held at Boston and Cambridge during the third week of August eventually reached 1,654. This is more than twice as many as have been enrolled in any previous congress. Especially remarkable is the apparent fact that more Europeans were in attendance here than ever on their own continent. Of the registration reckoned above, 1,229 names were entered in season to be printed on the program. A rapid and approximate check-up brings out the following facts. The number from outside the United States and Canada is 530, 43 per cent. of the total. Germany leads with 94. France and England appear to be tied with 74 from each. Italy follows with 43; other countries in order are Austria with 28, Hungary 26, Russia 25, Belgium 20, Czechoslovakia 16, Holland 15, Spain 14, Sweden 13, Japan 11, China 10. The total number of countries comes to about 39—subject to variation according to one's judgment as to whether provinces and colonies shall be distinguished. The representation of Latin America was not large—about 13.

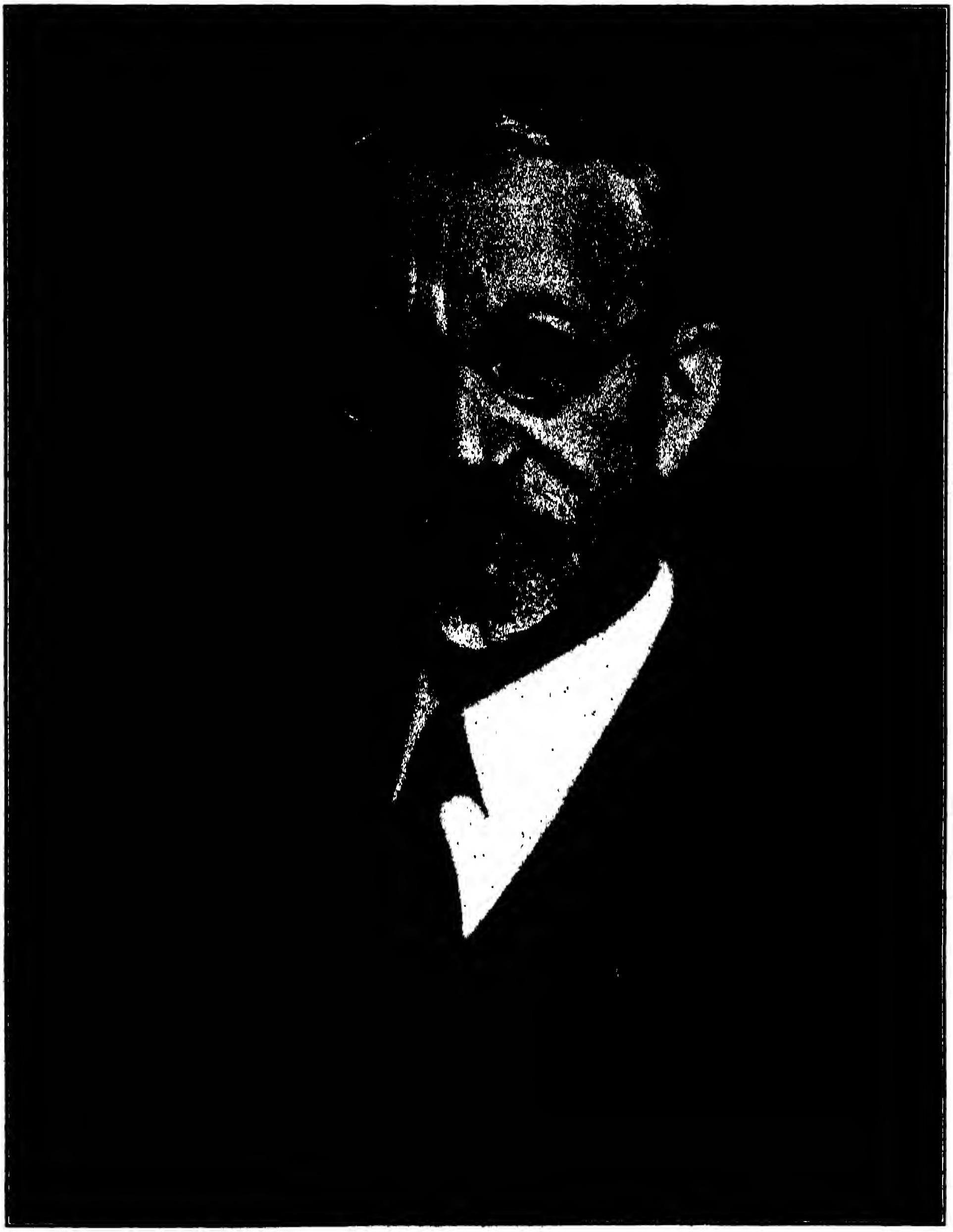
Analysis of the program shows that about 440 papers were given and 55 read by title. There were also some 78 demonstrations. As a rule, five or six sessions were progressing simultaneously, but by a well-contrived use of bulletin boards information was given in each room of the point reached in every other schedule; timely shifting was thus made easy. Of the papers read about 87 were in German, 47 in French and 18 in Italian. The general superiority in command of language manifested by our guests from abroad afforded food for reflection. A demonstration was given by Dr. Dusser de Barenne, of Holland, when he answered questions of Germans, Frenchmen and Americans each in their native speech. Even more impressive was the performance of Dr. Anrep when he swiftly rendered the Russian of Professor Pavlov into faultless English.

At the opening meeting, held in Sanders Theater, Cambridge, Surgeon-General Hugh S. Cumming, of the U. S. Public Health Service, gave an address of welcome on behalf of the United



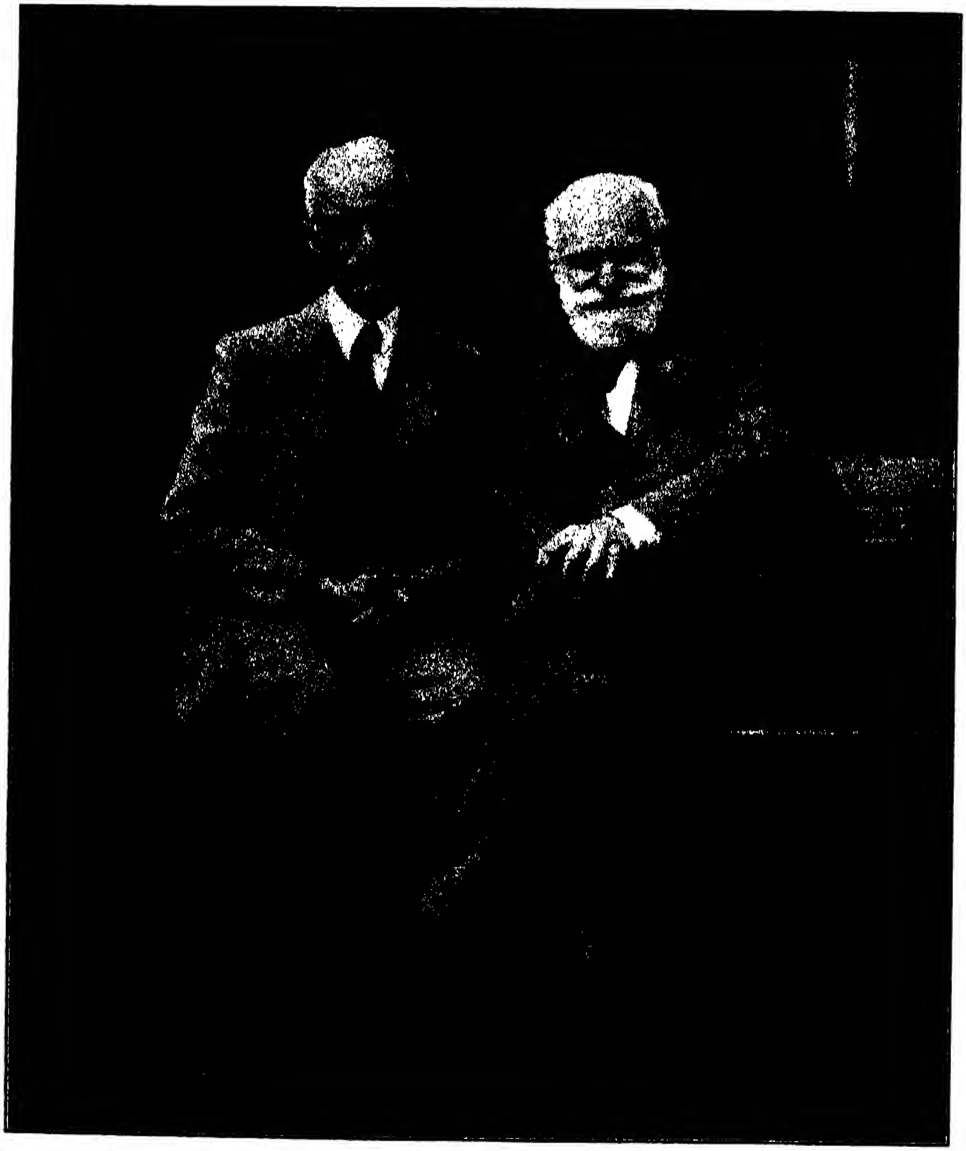
THE HARVARD MEDICAL SCHOOL

A PHOTOGRAPH TAKEN AT NIGHT ON THE OCCASION OF THE RECEPTION AND CONCERT OF THE BOSTON SYMPHONY ORCHESTRA, GIVEN IN HONOR OF THE THIRTEENTH INTERNATIONAL CONGRESS OF PHYSIOLOGY.



DR. WILLIAM H. HOWELL

PRESIDENT OF THE THIRTEENTH INTERNATIONAL PHYSIOLOGICAL CONGRESS. DR. HOWELL HAS BEEN PROFESSOR OF PHYSIOLOGY AT THE JOHNS HOPKINS UNIVERSITY SINCE 1888. HE IS NOW DIRECTOR OF THE SCHOOL OF HYGIENE AND PUBLIC HEALTH.

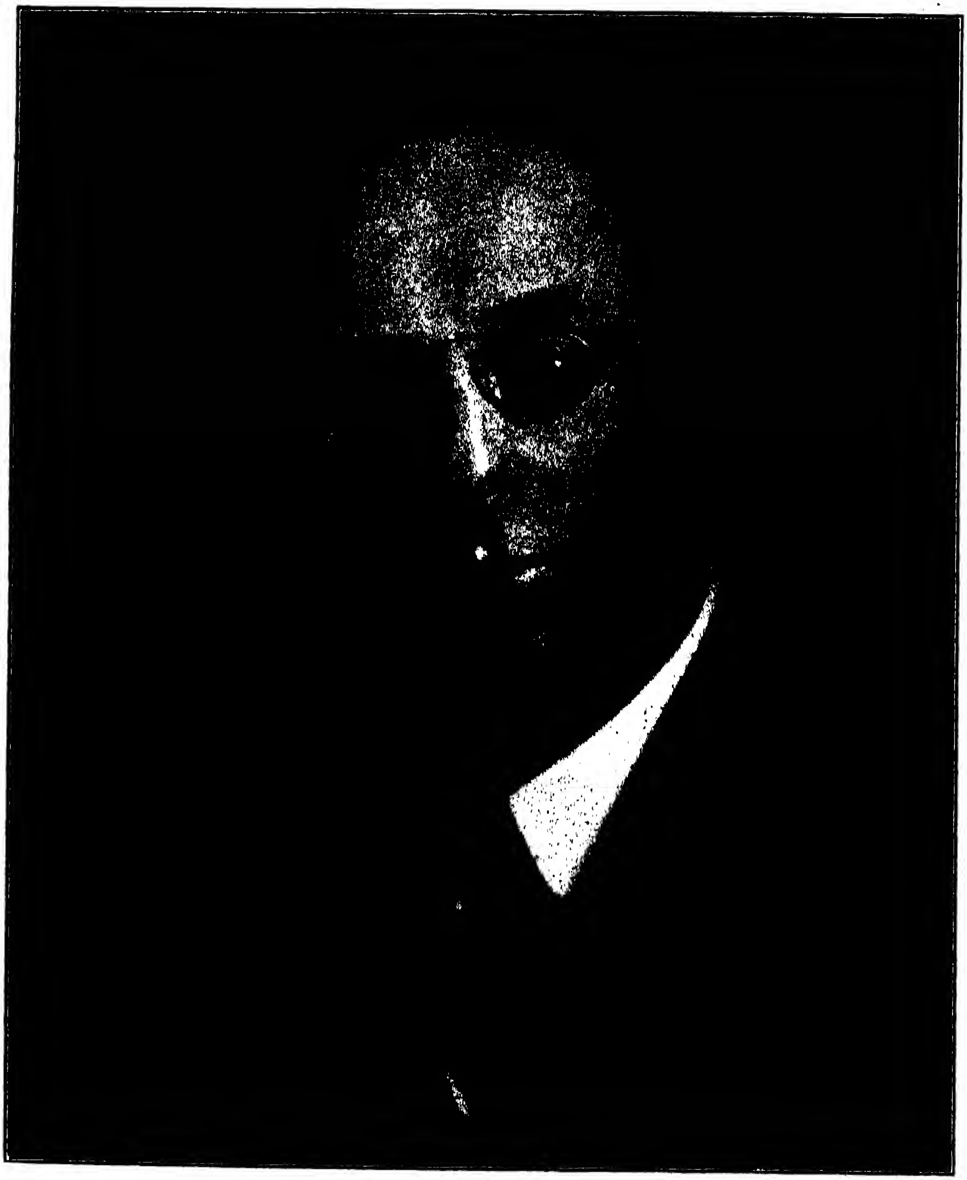


AT THE INTERNATIONAL PHYSIOLOGICAL CONGRESS

PROFESSOR PAVLOV, OF LENINGRAD, AND PROFESSOR CUSHING, OF THE HARVARD MEDICAL SCHOOL AND THE PETER BENT BRIGHAM HOSPITAL. PROFESSOR PAVLOV, A DISTINGUISHED MEMBER OF THE PHYSIOLOGICAL AND PSYCHOLOGICAL CONGRESSES, CELEBRATED IN SEPTEMBER HIS EIGHTIETH BIRTHDAY.

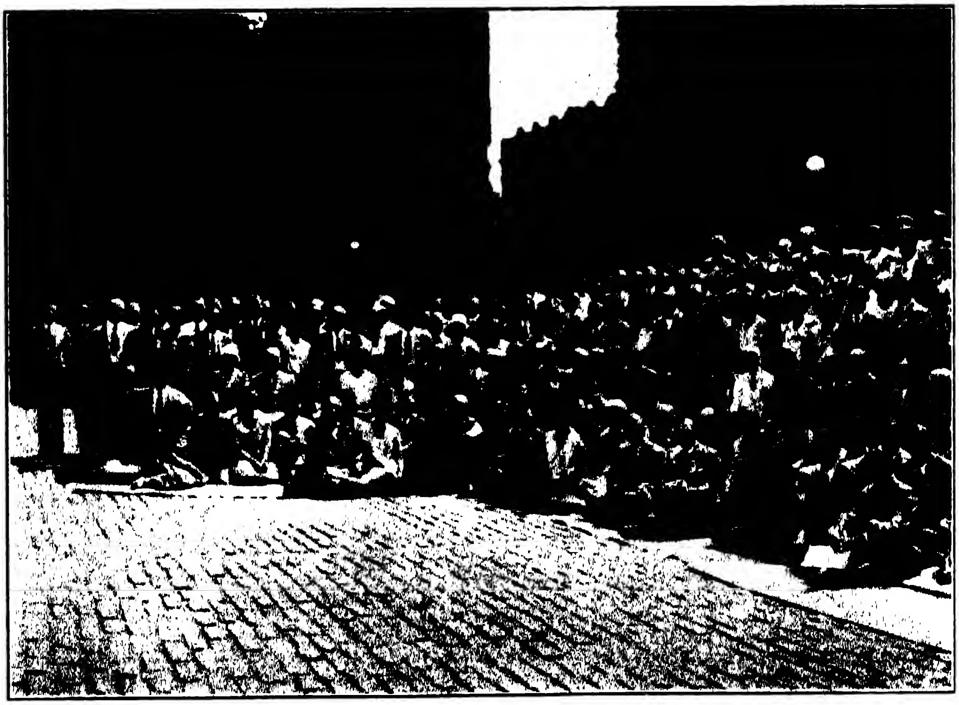
AT THE INTERNATIONAL PHYSIOLOGICAL CONGRESS
ON THE LEFT IS DR. REID HUNT, PROFESSOR OF PHARMACOLOGY AT HARVARD UNIVERSITY; IN THE CENTER, DR. ROSS G. HARRISON, PROFESSOR OF COMPARATIVE ANATOMY AT YALE UNIVERSITY; AT THE RIGHT, PROFESSOR W. H. HOWELL, PRESIDENT OF THE CONGRESS.

States government. He was followed by Lieutenant-Governor William S. Youngman who welcomed the members of the congress on behalf of the Commonwealth of Massachusetts. President A. Lawrence Lowell greeted the congress and welcomed it to Harvard University. The last of the addresses of welcome was delivered by the president of the congress, Professor William H. Howell, of the Johns Hopkins University. An address on "The Progress of Physiology" by Professor August Krogh, of the University of Copenhagen, was delivered following the addresses of welcome. Professor Krogh is director of the Zoophysiological Laboratory at the University of Copenhagen and a Nobel Prize winner for his work on the physiology of the capillaries. The formal dinner was presided over by Professor W. B. Cannon, of the Harvard Medical School. The 1,600 in attendance exceeded the capacity of Memorial Hall and overflow dinners with loud-speakers were necessary. At the closing exercises an address entitled "Reminiscences of the Early Days of the Physiological Con-



DR. JAMES ROWLAND ANGELL

President of Yale University and Vice-president of the International Congress of Psychology. Dr. Angell was professor of psychology at the University of Chicago from 1894 to 1920.



PSYCHOLOGISTS AT YALE UNIVERSITY

gresses'' was delivered by Professor Léon Fredericq, president of the Second International Congress, which was held in 1892 in Liége, where he is now professor emeritus.

It has been of interest to analyze the list of communications with the object of finding out whether particular subjects are receiving unusual attention. One might guess that this would prove true of the endocrine system, vitamins, the effects of radiant energy and electrophysiology. But when the tabulation is made the distribution seems to be remarkably impartial. If the chapter headings from a standard text were used to classify the titles there would be no disproportionate massing under any of them. There are workers in every field and they do not migrate in large numbers. One subject at least—H-ion concentration—does not loom so large as it did in programs of a few years ago. Moreover, many must have found it a heartening fact that a goodly proportion of the papers were frankly qualitative. Evidently there is still work for the non-mathematical physiologist.

The social features of the congress were memorable. Perhaps the scene which will most often be recalled was that presented by the great court of the Harvard Medical School on Wednesday evening. No setting could have been more stately or befitting the occasion. There was a soft and uniform illumination of the marble walls, with orchestral music. When the moon topped the copings a guest said to Dr. Cannon: ''That is the only thing about all this that seems real.''

PSYCHOLOGISTS AT YALE UNIVERSITY

A GROUP TAKEN IN ONE OF THE COURTS OF YALE UNIVERSITY SHOWS PART OF THE PSYCHOLOGISTS ASSEMBLED. SEATED IN THE FRONT ROW ARE MEMBERS OF THE AMERICAN NATIONAL COMMITTEE. BEGINNING AT THE CROSS ON THE LEFT ARE PROFESSOR ANGIER, OF YALE, CHAIRMAN OF THE LOCAL COMMITTEE; PROFESSOR LANGFELD, OF PRINCETON, FOREIGN SECRETARY; DR. ANGELL, PRESIDENT OF YALE AND VICE-PRESIDENT OF THE CONGRESS; DR. CATTELL, PRESIDENT OF THE CONGRESS; PROFESSOR WASHBURN, OF VASSAR; PROFESSOR PILLSBURY, OF MICHIGAN; PROFESSOR WARREN, OF PRINCETON; PROFESSOR BENTLEY, OF CORNELL; PROFESSOR HUNTER, OF CLARK, EXECUTIVE SECRETARY; PROFESSOR BORING, OF HARVARD, SECRETARY; PROFESSOR ANDERSON, OF MINNE-

THE NINTH INTERNATIONAL CONGRESS OF PSYCHOLOGY AT YALE UNIVERSITY

THE International Congress of Psychology met at Yale University from September 1 to 8, with a total attendance of 1,051. Of these 123 were from abroad, Canadians and Mexicans being counted as Americans. There were present 722 members and associates of the American Psychological Association, which is a remarkable record, for the association has in all 893 members with about 200 recommended for membership and included among those to whom invitations were sent. There were, in addition, 271 American members who were unable to be present, so the total membership was 993 from about 1,100 American psychologists. The situation thus differs from that of the Physiological Congress where foreign members and foreign papers were relatively more numerous. This, however, represents the international situation, for fully one half the psychologists of the world are Americans. In one of the papers presented at the congress it was shown that among the contributions abstracted in *Psychological Abstracts* during the past two and a half years, 5,449 were from

PSYCHOLOGISTS AT YALE UNIVERSITY

SOTA; PROFESSOR LASHLEY, PRESIDENT OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION; PROFESSOR PAVLOV, OF LENINGRAD; PROFESSOR DODGE, OF YALE, CHAIRMAN OF THE PROGRAM COMMITTEE. IN FRONT OF THOSE JUST MENTIONED ARE THREE OTHERS OF THE NATIONAL COMMITTEE, PROFESSOR SEASHORE, OF IOWA; PROFESSOR FERNBERGER, OF PENNSYLVANIA, AND PROFESSOR THORNDIKE, OF TEACHERS COLLEGE, COLUMBIA. STANDING ABOVE ARE FOREIGN MEMBERS OF THE CONGRESS; PROFESSOR CLAPARÈDE, OF GENEVA, PERMANENT SECRETARY OF THE INTERNATIONAL CONGRESSES, AND MME. CLAPARÈDE BEING MARKED WITH AN O.

the United States, 1,549 from Germany, 836 from Great Britain and its dominions, 811 from France, 218 from Italy, 149 from Russia and 371 from other nations. There were presented before the congress about 360 papers by Americans and 97 papers by foreign members.

The American members were from 42 states and from Porto Rico, Canada and Mexico. New York led with 196, followed by Massachusetts 80, Illinois 42, Pennsylvania 40 and Connecticut 39. Twenty-one foreign countries were represented, those with five or more members being England 22, Germany 17, Soviet Russia 10, Netherlands 8, India 6, Austria, France, Switzerland and Japan 5 each. Special invitations were sent to foreign nations through our Department of State. It is unfortunate that South America was represented by only one member.

At the opening session the members were welcomed to Yale University by President Angell, at the same time president of the university and vice-president of the congress. The foreign members were welcomed to the United States by Dr. William John Cooper, commissioner of education, who was summoned by telegram from Alaska by President Hoover to perform this office. The address of

PSYCHOLOGISTS AT YALE UNIVERSITY

the president, Dr. J. McKeen Cattell, was then given on "Psychology in America." There were but few formal meetings or entertainments at New Haven, but the arrangements for lodging in the beautiful Harkness dormitory and for meals in University Hall gave the best possible facilities for social meetings.

The program differed from that of the physiologists in that there were, each evening two lectures given by distinguished foreign members with one American, Professor E. L. Thorndike, and on one evening the address of the president of the American Psychological Association, Dr. Karl S. Lashley, now of the University of Chicago. There were usually three sessions in the morning for invited contributions, papers from foreign members here predominating. In the afternoon there were numerous simultaneous sections at which all psychologists who had research to report were given an opportunity. The discussions at these sections, often confined to a relatively small and definite field, were of special interest.

Arrangements for the entertainment of the foreign guests were not limited to the meetings at Harvard and Yale. Many of them were provided with lecture engagements before and after the congress which assisted in defraying the expenses of travel. For example, six state universities arranged to have as part of their summer sessions a course on psychology given by six distinguished foreign psychologists, each visiting the university for a week. After the Physiological Congress the foreign members were taken to Woods Hole by motor bus and then by boat to New York where a whole week was given to entertainments, excursions and visits to scientific institutions. An excursion was then made to Canada. The foreign psychologists were entertained before the congress at Princeton and Columbia and afterwards at Harvard, with trips arranged to Smith College, Clark University and Woods Hole.

THE SCIENTIFIC MONTHLY

NOVEMBER, 1929

BIOLOGICAL STATIONS OF JAPAN

By Professor M. F. GUYER

DEPARTMENT OF ZOOLOGY, UNIVERSITY OF WISCONSIN

THE MARINE BIOLOGICAL STATION AT ASAMUSHI

RARELY indeed can the zoologist command a modern, well-equipped laboratory and veritable fairy-land of natural enchantment all in one setting, but exactly this combination awaits the scientist who chooses to visit the Marine Biological Station at Asamushi. Situated on the northeastern coast of the main island of Japan, seventeen hours' rail journey from Tokyo and eight from Sendai, this up-to-date attractive establishment, which compares favorably in equipment with any marine laboratory in the world, offers its hospitality to native and foreigner alike. To speak of the low cliffs, the rocky beaches, the wild, indented shore-line, the mountainous hills which spring abruptly from the sea, the beckoning coves and channels, is but to catalogue the material realities of the place, whereas it is, in fact, an indescribable ethereal quality which lays

GENERAL VIEW OF ASAMUSHI,
A SUMMER RESORT WITH HOT SPRINGS AND EXCELLENT SEA-BATHING, ABOUT TWO MILES DISTANCE FROM THE STATION.

VIEW OF THE AQUARIUM BUILDING

(WITH CURVED ROOF) AND THE MAIN LABORATORY BUILDING BEYOND AS SEEN FROM A NEARBY HILL.

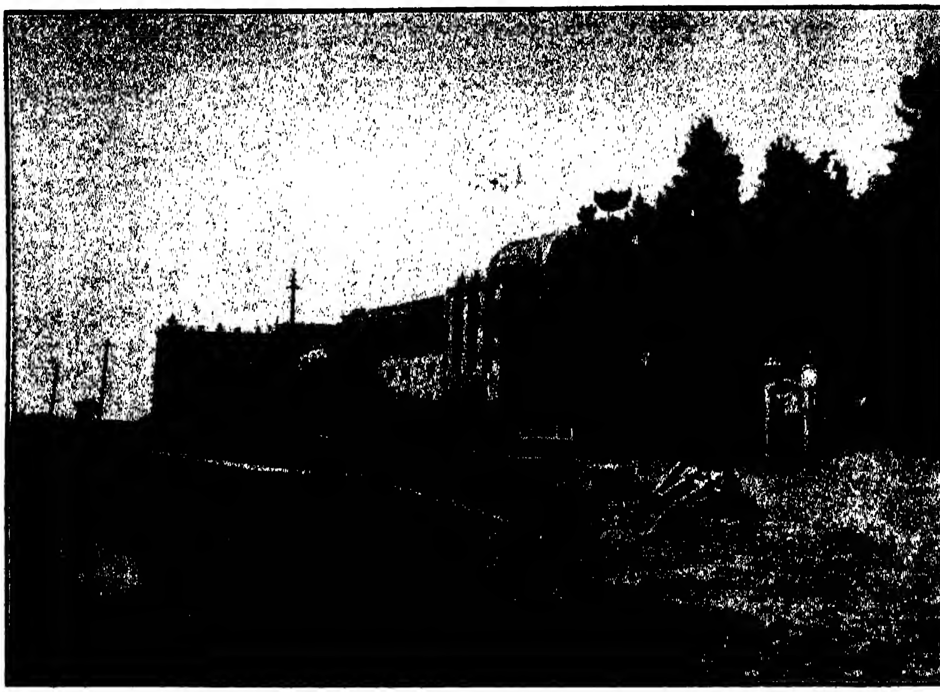
DORMITORY AND REFECTORY WITH OFFICIAL RESIDENCES BEYOND.

hold of the senses when one visits this land of pastel hues, mysterious hazes and cameo-cut perfections.

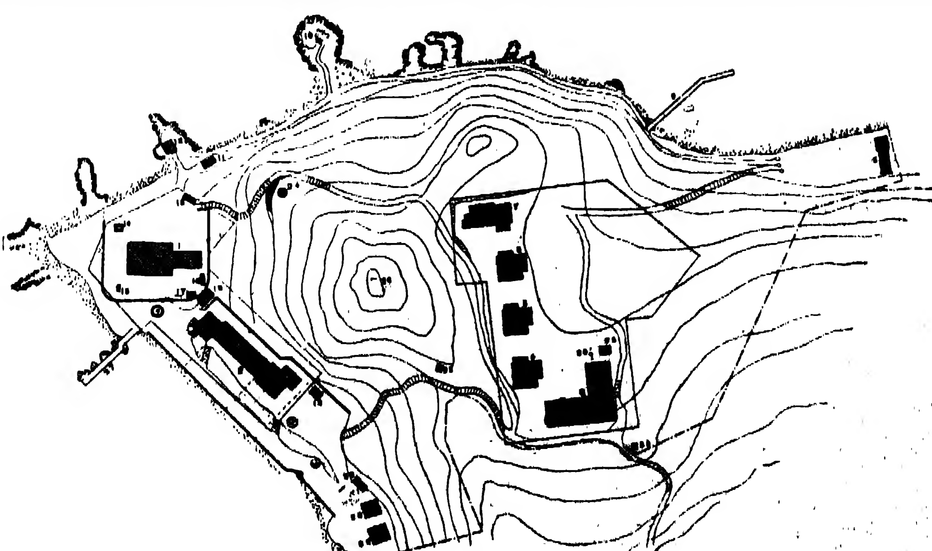
Although located in a part of Japan where little English is spoken, American students need fear no serious linguistic inconveniences, for the hospitable director is none other than Professor Shinkishi Hatai, so closely identified with American zoology through over twenty-five years of sojourn in the Universities of Chicago and Cincinnati and the Wistar Institute, that we regard him as practically one of our own citizens. Speaking English himself and with four children reared in the schools of America it is needless to say that English is almost as current a language at the station as Japanese itself.

The station was founded in July, 1924, and is an extension of the Institute of Biology, Tohoku Imperial University, of Sendai, Japan. Although intended primarily for the students and faculty of its own university, investigators are welcomed at any time. The dormitory and staff residences are open the year round, although summer and autumn are the seasons of greatest activity. In the summer of 1928 the staff and employees numbered fourteen, with Professor Hatai as director, Assistant Professor Seiji Kokubo, administrator, and three assistants—Shunichi Takasuki, Yoshiro and Sadao Tanohe—serving as resident naturalists.

The chief structures consist of a commodious, well-equipped laboratory building, a large concrete aquarium building which houses a series of beautifully maintained aquaria and a museum, a combined dormitory and refectory which accommodates about fifty persons, and four official residences. A unique feature of the station is an under-sea laboratory designed for studies in experimental evolution, physiology and ecology. This building is half submerged in the sea at the shore-line with the floor about six feet below sea-level. The aquaria in it are supplied by the ebb and flow of natural sea-water, with temperature, salinity and other conditions similar to those of the open sea, so



NEARER VIEW OF AQUARIUM BUILDING AND THE MAIN LABORATORY.



PLAN OF BUILDINGS AND GROUNDS

1. Laboratory. 2. Aquarium house. 3. Boarding house. 4, 5, 6, 7. Residences. 8. Boat house. 9. Breakwater. 10. Marine pool. 11. Pumping house. 12. Undersea laboratory. 13. Electric plant. 14. Aquarium. 15. Meteorological screen. 16. Gas generating plant. 17. Storage. 18. Reserve house for living fishes. 19. Toilet. 20. Monkey house. 21. Bird house. 22. Bird house. 23. Monkey house. 24. Salt-water tank. 25. Fresh-water tank. 26. Flag pole. 27. Pier. 28. Storage. 29. Well. 30. Fresh-water well.

that experimental marine animals may live under practically normal conditions. Lighting can be controlled at will.

The main laboratory is a two-storied brick building with eight research rooms for the faculty, a large laboratory for general students, a physiological laboratory, a biochemical laboratory, a darkroom and sundry other rooms all furnished both with running sea and fresh water. This building also houses the library.

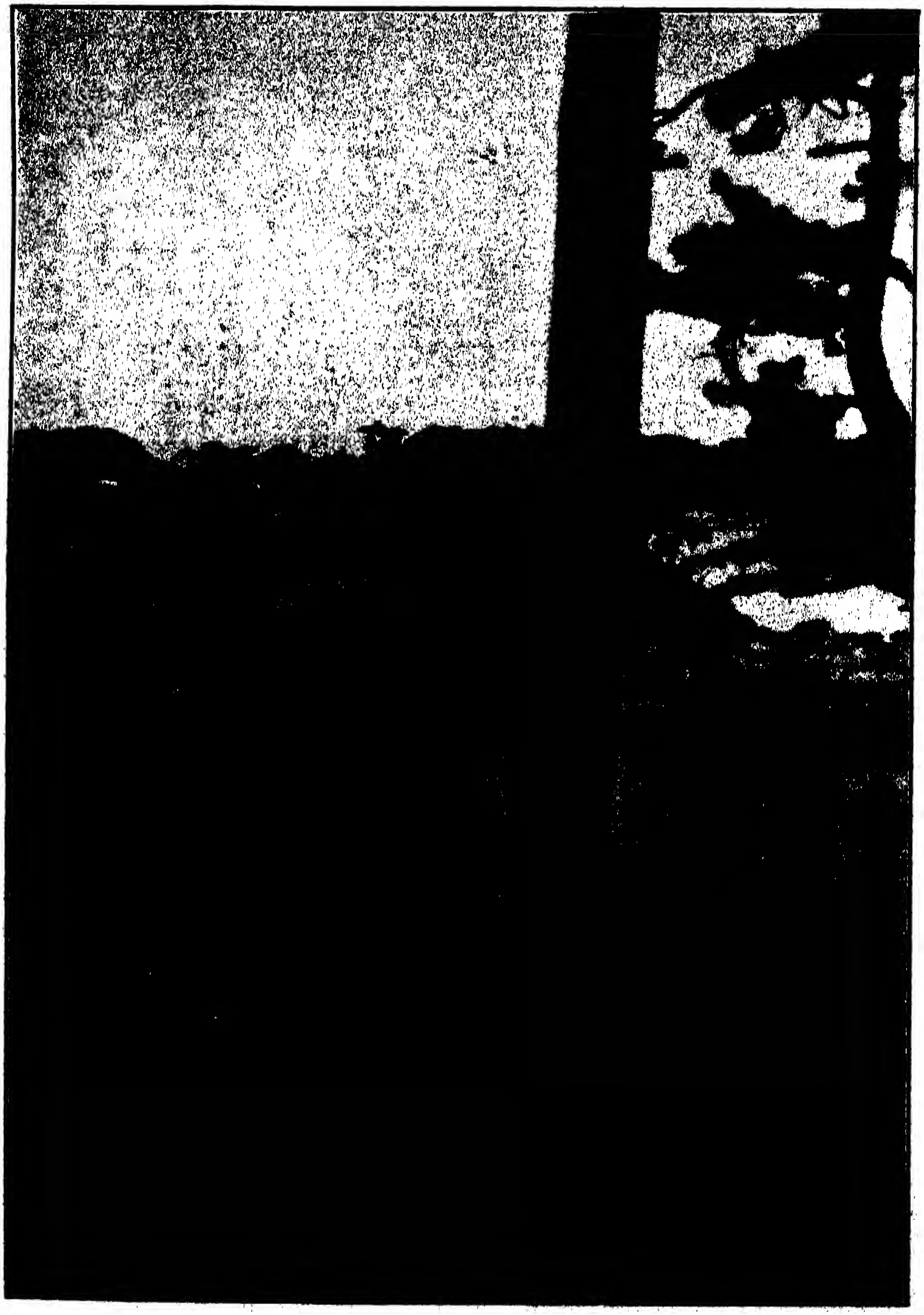
Two motor-boats are used in collecting and transporting various marine forms during all but the coldest part of the year. The exhibits in the aquarium building are discontinued for the winter in November of each year. Although the fauna and flora are less rich than those of southern Japan, an unlimited supply of the larger starfishes, ascidians, brachiopods, Pectens and Caudina is easily available and supplies the needs of students of experimental zoology and physiology.

The steady stream of publications which issues from this station abundantly testifies to the zealous activity of Director Hatai and his associates. The accompanying photographs give some idea of various features of this splendid, modern institution.

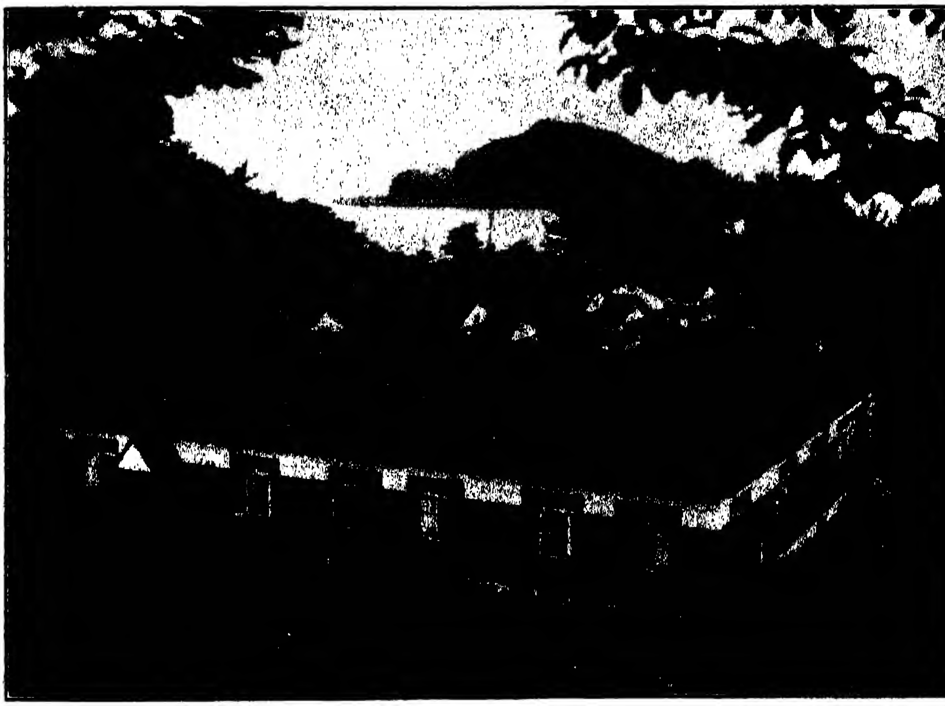
THE MISAKI MARINE BIOLOGICAL STATION

Less than three hours' rail journey from the busy life of Tokyo, amidst a romantic setting of both landscape and history, is situated the Misaki Marine Biological Station. It lies in about the same latitude as Los Angeles, on the southern extremity of a peninsula which separates the Bay of Tokyo from Sagami Sea. Just as the Marine Laboratory at Woods Hole in America prides itself on its early associations with Agassiz so this Japanese station is linked even more closely with the late Professor Mitsukuri, who was to zoological science in Japan much what Agassiz was in America. The Misaki laboratory, indeed, antedates that at Woods Hole by one year. It was originally erected in

THE MISAKI MARINE BIOLOGICAL STATION; DR. YATSU AT THE OARS.



A BIT OF THE SHORE AND THE RESEARCH LABORATORY OF THE STATION, VIEWED FROM A NEARBY HILL.



SEASIDE CLUB FOR STUDENTS,
DINING-ROOM AND SOCIAL HALL.

1887 by the Japanese Department of Education, at the suggestion of Professor Mitsukuri. The three great guiding spirits of this laboratory who have been its successive directors—Mitsukuri, Iijima and Yatsu—are too well known to American zoologists to require comment.

Though fascinating ruins and legends claim the attention at every turn on the peninsula, and pine-covered hills with beautiful vistas of sea and mountain invite one to linger and dream, the outstanding attraction to the zoologist is the laboratory and what goes with it. No marine station in the world, not even the far-famed ones of the Mediterranean, can outvie that of Misaki in variety and richness of fauna and flora. Tide-pools, rocky shores, sandy, stony or rocky beaches, mud flats, projecting ledges, cliff caves, all combine to form a "happy hunting ground" for the zoological enthusiast. Also, in the winter months when strong west winds blow, an amazingly rich plankton is driven into the inlets from its usual home in the "Black Current." One then may find *Salpae, Porpitae,* various interesting Heteropods and Pteropods, compound Radiolarians, *Auriculariae,* and what not. Within half a mile of shore one may reach a depth of ten fathoms, and three or four miles out a depth of one hundred fathoms, beyond which deep-sea forms of wonderful variety and beauty dwell. Exquisite glass sponges, stalked crinoids, large sea-spiders, red brittle-stars, giant crabs which measure ten feet from claw to claw, orange-colored hydroids standing a foot high, unique octopi and gelatinous sea-cucumbers may be found. There, also, live luminous black sharks and archaic sharks with more than five gill-clefts.

With the appointment of Professor Yatsu, of Tokyo Imperial University, to the directorate, in addition to facilities

JAPANESE FISHING BOAT
SAILING FROM THE STATION.

for faunistic studies, the equipment has been expanded to provide for physiological and chemical work. Regular courses are given in marine zoology for biology teachers, in fisheries and in planktology and oceanography. It is to the investigator, however, that the laboratory holds out the greatest attraction.

The station proper consists of four buildings: (1) a library and herbarium of land and marine plants together with research rooms for investigators; (2) a general student laboratory; (3) an aquarium and motor room, and (4) a two-storied museum in which are two bedrooms for overseas investigators. In addition are the various homes of the staff.

One has only to climb Azalea Hill, a pine-clad elevation ornamented with wild azaleas, to get an "aeroplane" view of the whole surrounding region of romance and beauty. Directly across the bay, towering high above the sea, stands sacred Mount Fuji.

The following interesting account of the effect of the great earthquake of 1923 on the fauna and flora of the region is given in the words (written in 1926) of the present director of the station, Professor Naohide Yatsu:

With the first and greatest shock the water rushed out of the inlets with tremendous rapidity. The sea then rose higher and higher—very much higher than at high tide—and the water receded for good. The land was thus raised nearly four feet above its former level. The elevated part can now be seen as a whitish zone with dead barnacles and oyster-shells. In passing, it may be mentioned that most of these dead barnacles (*Tetraclita porosa*) are now occupied by spiders. The drying up of the sand beaches and mud flats killed all the dwellers there, such as cake-urchins, bivalves and annelids. Most of the green algae, *Reniera*, a very common sponge encrusting the rock, disappeared, but in the past two years new colonies have established themselves, springing from those that survived. The red actinians (*Actinia equina*) are gone forever, but the *Onchidia* are coming back.

That immense quantities of shore-sponges were killed by the earthquake can be seen from the sudden increase of monoaxon spicules in the beach sands.

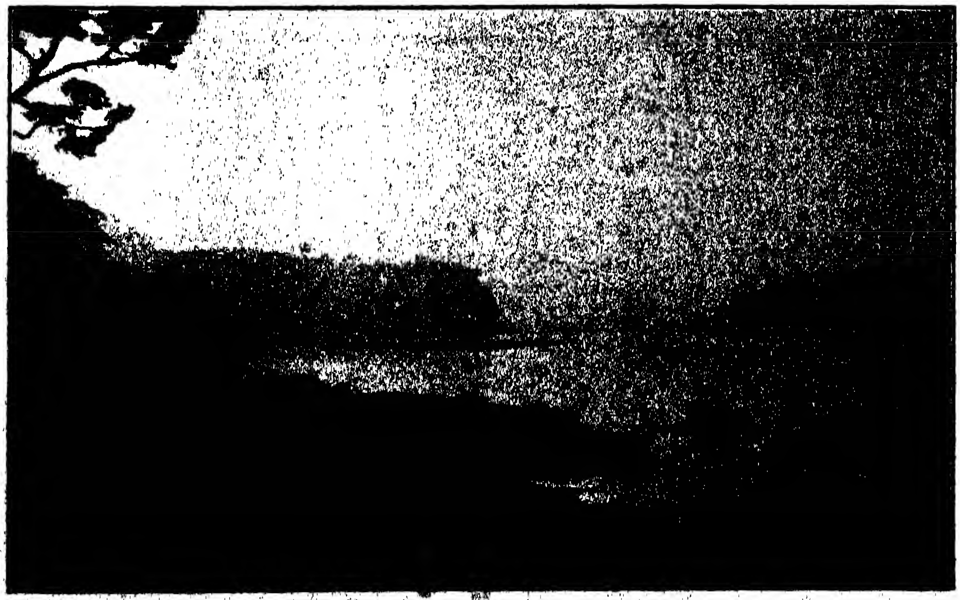
On the morning of the earthquake, fishermen out on the fishing ground found many dead deep-sea fish of the cod family (*Physiculus*)

floating on the surface of the sea. At this phenomenon they were frightened, thinking something unusual would happen, and so they at once hastened back to land. There they soon witnessed what the earthquake had done. Undoubtedly the fish were killed by the sudden rushing of water into a newly formed depression at the bottom of Sagami Sea.

One more thing worth mentioning is that cicadas had been very abundant every year before the earthquake, but in the two summers after the disaster the cicadas considerably decreased in number. This was, I think, due to the fact that the larvae were crushed in the earth during the earthquake.

Quite recently two places of unusual scientific interest have been discovered near the laboratory by A. Imamura, professor of seismology at Tokyo Imperial University, one on an almost vertical cliff just below Arai Heights and the other on a hillside close to the rice-fields at the head of Moroiso Creek. At the latter place he found four rows of holes in the rock, one above another with intervals varying from 1.5 to nearly 3 meters. The holes were once inhabited by date-shells (*Lithophaga nasuta*), a species closely allied to *L. dactyla*, the holes of which made the pillars of the so-called Temple of Serapis at Pozzuoli very famous. Professor Imamura can tell us from these holes the approximate year in which took place four sudden upheavals of land due to earthquakes comparable in magnitude to the one which occurred in 1923. The lowest row indicates the high-tide mark prior to the earthquake of 1703.

The accompanying photographs, supplied through the kindness of Dr. Oshima, speak for themselves regarding the comforts, beauty and attractions of the place. Nowhere in the world will the American zoologist meet greater courtesy and hospitality than at the hands of the friendly director, Professor Yatsu, who is already widely known and beloved of American zoologists.



VIEW OF ABURATSUBA BAY

WHERE THE STATION IS LOCATED. A FLOAT FOR OYSTER CULTURE IS SEEN IN THE DISTANCE, AND DR. OSHIMA AND STUDENTS IN THE BOAT.

THE GERMAN CARP, AN INVITED IMMIGRANT

By Professor W. M. SMALLWOOD and MARY L. SMALLWOOD

DEPARTMENT OF ZOOLOGY, SYRACUSE UNIVERSITY

THE immigrant has come to have an important place in our twentieth century thinking. Congressmen are besieged with propaganda in behalf of each of the various nationals, but less of popular thought is given to the many animal immigrants, although they frequently cause the greater economic problem.

Most of our attention as scientists has been given to the economic aspects of these entrants as they affect our agricultural products, while in contrast to this careful study the life of the immigrant animals in our fresh waters has been scarcely touched. One of the reasons why this interesting problem in adaptation in a nearly uniform environment has been neglected is due to the difficulties in the problem itself. This article aims to assemble some observations on the immigrant carp in the hope of throwing light upon the adaptations of this very old fish as it has adjusted itself to our American waters. The observations are of too preliminary a character to justify any far-reaching conclusions, but it is our thought that this summary may serve as a starting-point and that in a few years adequate interpretation can be made.

De Kay places the first introduction of carp into New York waters at 1831. These were reared in ponds and later placed in the Hudson River.

Another of the early references to the successful introduction of the carp into America is found in the *Transactions of the American Institute* for 1850, and reads as follows:[1]

Mr. Meigs.—We are pleased to see among us Captain Robinson, of Newburgh, who brought the carp from England several years ago—thus conferring a great benefit upon this country by adding a fish before that unknown in our waters.

Captain Robinson.—I brought the carp from France about seven years ago, put them in the Hudson River, and obtained protection for them from our legislature, which passed a law imposing a fine of $50 for destroying them.

There is evident pride in this report, and the fact that a fine for destroying carp had been authorized by the legislature indicated great expectations as to the quality of this foreign fish. Various other attempts were made to introduce the carp to American waters, and as soon as the U. S. Fish Commission was established, the commissioner of fisheries gave attention to the importation of carp from Europe. By 1877, shipments were made from Washington and the applications came in so rapidly that, in 1882, seven thousand requests for carp were received. The distribution of carp continued until 1896. From that time on this fish had become sufficiently adapted to our American waters to need no further fathering care from the Bureau of Fisheries; in fact, it took so kindly to the American environment that it developed and spread until it is to-day regarded as a menace in a large number of our fresh-water ponds and streams. By some strange coincidence the English sparrow was introduced in the same year, 1850, with the hope that it might feed upon some of our noxious insects. The story of the distribution of the English sparrow, which has only recently ceased to be a serious pest, is well known. Will the immigrant carp pass through a similar series of adjustments?

During the summer of 1927, the New York State Conservation Commission undertook an extensive study of the carp problem which was continued in 1928

[1] Leon J. Cole, 1905, "German Carp in the United States." Report of the U. S. Bureau of Fisheries, pp. 523–641. Illustrated.

and will no doubt be carried on for some time. The writers of this article were members of the scientific staff for the Oneida Lake Survey of the Carp Control Studies in 1927, and have drawn largely upon the data collected then and in 1928, as well as upon their own studies,[2] for facts stated here.

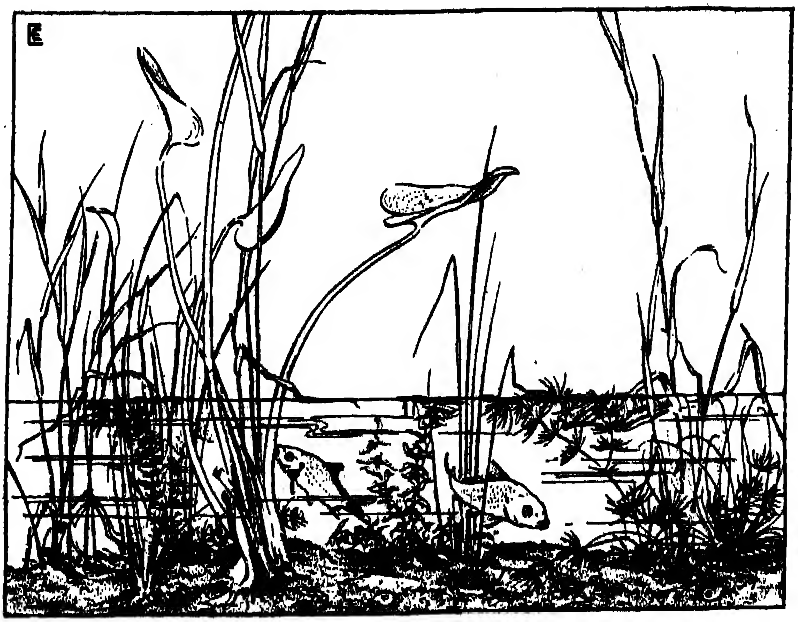
During the latter part of June, depending upon the temperature of the water, the carp seek the bays of Oneida Lake and deposit their eggs on the shore plants. The filamentous algae, *Chara*, and the small *Potamogetons* are covered with masses of eggs. During the summer of 1928, eggs were very abundant from June 26 to July 5, although the spawning period ranged from May 14 to July 7. We were able to hatch eggs in the pike-perch hatchery jars of the Constantia Hatchery, although eggs placed in the bass net cages in the shallow waters at the edge of the lake died within three days.

The carp eggs in the jars hatched in from five to seven days, although the usual time given is from twelve to fifteen days. The embryo begins to move within the egg envelope in two days. This rate of development is very rapid and the eggs of the same batch hatch into active swimming forms at variable periods of about twenty-four hours. The mortality of the eggs on the shore was very great as these were noted from day to day. The eggs which were not developing turned whitish.

[2] W. M. Smallwood and Parke H. Struthers, Conservation Commission, 1928, "Carp Control Studies in Oneida Lake."

—*New York State Carp Control Studies*

FIG. 1. WEIGHING, MEASURING AND TAKING A SCALE FROM AN ADULT CARP FOR AGE DETERMINATION.



—*Illustration from New York State Conservation Commission*

FIG. 2. HABITAT SKETCH OF YOUNG CARP IN THE ADVANCED FRY STAGE.

As soon as the young carp escape from the egg envelopes and become free swimmers, they are not found living in schools as is the case with the adult carp and many of the young game fishes. The young carp can be easily distinguished from the young of other fish since they are a replica of the adult in form and in arrangement of fins. The back is much lighter in color than that of the adult, being a light mouse gray. At the base of the tail there is a vertically placed black bar, while the abdomen has a distinct yellowish tinge. When young carp are caught in a dip net this yellowish color and the deep body distinguish them from the very similar young suckers.

The young carp take up a habitat that is quite characteristic, in water that is free from sediment, decaying vegetable matter or contamination from creeks. The temperature of the water in these protected regions runs about ten degrees warmer than that of deep lake water. The shores bordering these carp habitats consist of low land covered with a growth of meadow grass or bulrushes with here and there small bayous extending shoreward. Each of these setbacks is carpeted with tender grass, with *Elodea*, *Chara* or *Myriophyllum*, in which the young carp live. As the carp increase in size, they move lakeward into deeper water. By September first, the young carp are living in one or two feet of water close by scattered beds of *Potamogeton pectinatus* or hornwort.

Invariably little carp will hide rather than seek safety in flight if molested. It is this characteristic which makes them so difficult to find. When catching them with a hand-net, it is possible to work over a whole bed of *Chara* or *Elodea* without driving the fish away. Not until they reach a length of about 100 mm do they seem to appreciate the possibility of fleeing from an intruder.

Small carp are very sensitive to temperature changes and also to impurities in the water. To test these reactions, young carp were placed in aquaria

with young sunfish, bullheads and common perch. A sudden change of temperature invariably affected the carp first. Any pronounced change in the hydrogen ion concentration, due to the presence of decaying matter, was fatal to the carp, although not to the other young fishes living with them. In these lake habitats young carp were never found in the vicinity of green algae such as *Spirogyra* or *Cladophora*, decaying vegetable matter or quagmires.

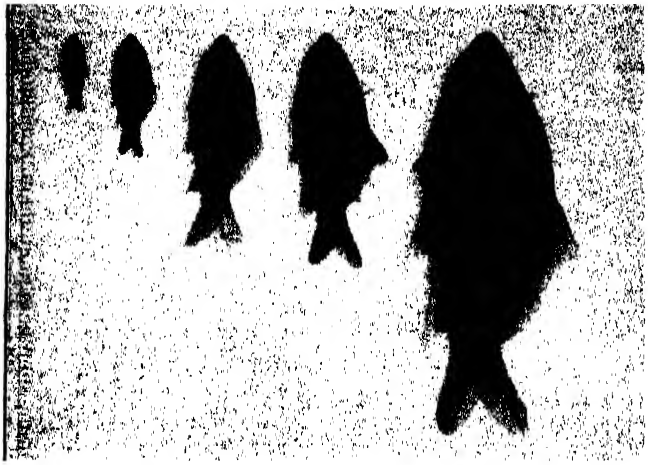
The rapid rate of growth of young carp is remarkable. This is shown in the following table, which gives the dates the fish were caught and the ranges in size in Oneida Lake.

July 12	10 mm long
July 21	12 mm– 26 mm
July 27	14 mm– 30 mm
July 29	12 mm– 40 mm
Aug. 12	38 mm– 42 mm
Aug. 20	41 mm– 78 mm
Sept. 5	80 mm–112 mm
Sept. 7	72 mm–106 mm

The feeding habits of young carp are very interesting as they were observed on Oneida Lake during the carp control studies in 1927. The fish places the mouth against the base of a stalk of *Chara* and draws into the mouth the minute animals, such as cyclops and daphnia, which are feeding on the stalk. The fish moves slowly up the stem on one side, then turns and cleans off the other side as it moves down to the base again. After this, the fish moves to another plant to repeat the operation. At times they work out onto the leaves, but never come to the surface of the water. Sometimes two fishes are working on one plant, each apparently unconscious of the other's presence. At intervals, a fish remains motionless, except for the slowly waving fins, and then darts off to a new clump of *Chara*.

More detailed observations of the feeding habits of the little carp were obtained from fish living in aquaria. The bottom of the aquarium was covered with fine sand and clay rich in organic material. Within a few days the surface showed numerous small pits. These were made by the young carp which often take a position forming an angle of about 90° with the bottom, and with the tip of the snout in the sand. Next, a cloud of sand is seen passing out of the opercular opening. Sometimes this is all that happens and the fish proceeds to swim about in the aquarium; but at other times the fish takes a position horizontal to the bottom and works the jaws repeatedly as if chewing, the jaws opening and closing from twelve to eighteen times. They also suck up a mouthful of the debris from the bottom, eject this from the mouth, then dart forward and gobble up bits of desirable food. The young fish living in aquaria frequently resort to top feeding, working here and there with their mouths just below the surface of the water, sucking up bits of floating matter. This is probably an unusual type of feeding for young carp in their natural haunts, for the fish lives near the bottom. Observations made on the stomachs of little carp taken at different hours indicate that they have rapacious appetites which compel them to forage for food at all hours of the day.

Young carp are very active, strong swimmers, and their inquisitive natures keep them continually exploring the domain in which they live, but they are so much more timid than our common game fish that it is difficult to observe them accurately. Their tendency to live in dense growths of water plants and to bury themselves in the mud indicates that the young fish may be, to some extent, negatively phototropic, in which respect their behavior differs from that of the adults, which show no aversion to light. The instincts seem to be poorly developed in the young carp, for they show no indications of pugnacity or, on



—*Photograph furnished by New York State Conservation Commission*

FIG. 3. YOUNG STAGES OF CARP. THE TWO SMALLEST FROM ONEIDA LAKE, JULY 21, 1927; YOUNG LEATHER CARP FROM CASSADAGA CREEK, JULY 14, 1925; LARGEST SPECIMEN FROM ONEIDA LAKE, SEPT. 15, 1927.

the other hand, of a tendency to be gregarious. A characteristic occasional darting about aimlessly through the water might be attributed to play.

Yearling carp range in length from six to ten inches. Bean[3] reports a growth of twenty-three inches in eleven months, a rate of growth which our study does not support. The two-year-olds grow rapidly in weight and in length but with no steady rate. There is a wide range in the weight and length of carp taken in a lake habitat where there is an abundance of food. Our studies indicate a wide range in growth. Sixty-two individuals that were judged to be five years old by the lines of growth on the scales ranged in weight from four to eleven pounds and varied in length from sixteen to twenty-six inches.[4] This variation in length and weight in the five-year age which was common in the specimens studied indicates that there is little significance in the older tables such as those published by Goode. This conclusion is further emphasized when we compare the range of weight for fishes in Oneida Lake having the same length, as indicated in the table.

The heaviest fish taken during the carp control studies weighed thirty-four pounds; while fifty-pound fish are reported from the Oswego River, it has not been possible to locate the man who weighed them. Bean reports European carp weighing sixty-seven and even ninety pounds, but gives the date, 1853. There are various extraordinary sizes that have been reported, mostly for European carp, but for which no exact data are available. The age of carp is perplexing; Bean reports one that attained an age of thirty-five years, but does not indicate the source of his information. Baird and Suffield report ages of 375 and 300 years.[5] The oldest carp taken by the carp control workers in 1927 was only thirteen years, when computed by the scale lines of growth. Does

[3] T. H. Bean, "New York State Fishes." 1903.

[4] For details see table in "Carp Control Studies." 1928.

[5] S. F. Baird, "Death of An Aged Carp," *Am. Rec. Sci.*, p. 262. 1872.

R. R. Suffield, "Longevity of the Carp," *Nature*, 10: 147. 1874.

VARIATION IN RANGE OF WEIGHT OF FISH OF THE SAME LENGTH TAKEN IN THREE HAULS OF THE SEINE IN ONEIDA LAKE IN 1928

Number of Individuals	Length in Inches	Weight in Pounds
1	7.5	0.7
1	11.5	1.25
1	12	1.4
1	13	1.5
1	14	2
2	15	2, 6
3	16	4, 5, 6
4	17	8, 5, 6, 5
5	18	5, 3, 4, 4, 3
6	19	5, 4, 5, 5, 4, 5
6	20	6, 7, 5, 5, 5, 6
12	21	6, 7, 7, 7, 7, 7, 7, 7, 6, 6, 8, 5
5	22	8, 7, 8, 10, 8, 9
9	23	13, 8, 9.11, 9, 9, 8, 8
5	24	10, 9, 10, 8, 9
5	25	10, 12, 10, 8, 9
5	26	13, 12, 10, 12, 10
5	27	14, 16, 18, 12, 11
3	28	12, 14, 14
4	29	15, 15, 15, 20
2	30	20, 18
4	31	18, 20, 24, 20
3	32	21, 20, 23
2	33	20, 20
1	34	21.5
1	35	24.75
1	39	29
1	40	32

this mean that they have been in Oneida Lake but thirteen years? This can hardly be the explanation, for they were placed in the Hudson River in 1831 when the Erie Canal had been completed for six years. Carp in the Hudson River would have easy access to the Erie Canal which would permit them to enter the numerous streams, ponds and lakes from Albany to Buffalo. It seems safe to assume that carp have been in Oneida Lake for much more than thirteen years. Where are the older carp?

In the early spring the carp are found in swamps and submerged lowlands where they may become stranded. As the warm weather of April comes on they begin to migrate to the shores from the swamps and from the deep water of the lake, becoming abundant in the shallow bays where vegetation is profuse. Here spawning takes place in June and July. After spawning, very characteristic schools of these immigrants may be found for the rest of the season in the shallow bays having abundant growth of pond weeds, a muddy or sandy bottom and a nearness to deep water. Because of their presence in such bays, they can be very conveniently baited with bread and corn, and consequently more easily seined. Until recently, carp have not been seined extensively in this country, since only certain groups of people have appreciated their value as a source of food.

The every-day diet of these immigrants may be summarized as "mites, entomostracans, oligochaetes, amphipods, snails, protozoans, silt, debris," according to one writer; and, according to another, as "principally vegetable matter, also insect larvae, crustaceans, mollusks and other aquatic animals," or they are "omnivorous and chiefly vegetarian in their diet." In the two years' work of the carp control studies on Oneida Lake and its tributaries, the food was found to be chiefly animal.

Carp are found inhabiting lakes, ponds, streams and canals. Such habitats vary in currents, amount of suspended matter, temperature and vegetative growth. In the large lakes the environment is practically stable, while in the shallow streams or the canal, temperature changes are more rapid and there is an extensive plant growth and even a large degree of pollution.

The question naturally arises as to how the carp has become adapted to such widely different habitats and able to flourish in all of them. Though it is to be noted that adult carp live in communities of their own nationality and that bass and pike move off the feeding grounds when a school arrives, there is more or less competition with the more

—*Photograph furnished by New York State Conservation Commission*

FIG. 4. A BOAT LOAD OF CARP—PART OF A CATCH WEIGHING ONE AND A HALF TONS.

highly specialized fishes. Like some of our human immigrants, the carp have come from crowded conditions in other countries where they were accustomed to live on inferior food. These same habits are retained in our spacious waters where they survive and reproduce under a more varied environmental condition than any single species of our native fish.

One phase of this adaptation may be in the food habits. Is there any other fish with such a cosmopolitan, yet plebeian, appetite? It would seem that in this respect our hardy immigrant has a distinct advantage over other fish which may be due in part to the peculiarity of its intestinal tract. In the adult there is a large intestine, but no stomach, and a combined liver and pancreas. The significance of these structural peculiarities is not fully understood as yet and is one of the problems that we are investigating.

During the summer of 1927, nearly fifty tons of carp were taken from Oneida Lake in the carp control studies. This would represent about nine thousand carp, ranging in age from three to thirteen years. In this large number there were no evidences of disease, and practically no abnormalities. A great many specimens exhibited from one to one half dozen lamprey scars, but in all our study of the shores of Oneida Lake, which has a shore-line of about sixty-five miles, we failed to find any numbers of dead carp. The observations extended from the middle of June until the middle of September. Similar observations in the summer of 1928 covered not only the lake, but all the Erie Canal from Utica, Lock 20, west to Lock 25, the Oswego Canal, Onondaga and Cross Lakes. This territory, covered by Professor Struthers,[6] represents three hun-

[6] Parke H. Struthers, "Carp Control Studies in the Erie Canal." New York State Conservation Commission Report for 1929. In press.

dred miles of actual shore-line. It was surveyed twice during the summer. This absence of disease in the lakes and streams and Erie Canal is duplicated by the observations of Professor R. V. Bangham, for Ohio, Professor A. C. Pearse, formerly of the University of Wisconsin, and Dr. George Hunter III for the Illinois region.

It is also to be noted that we found the carp to be remarkably free from parasites. The three men just noted report a similar freedom from parasites in the regions which they have studied. Ward, in 1912,[7] and Essex and Hunter, in 1926,[8] agree that the carp is relatively free from parasites. The only parasites of any frequency at all are forms that belong to Acanthocephala (hook-headed worms). These observations cover the Mississippi River basin. During the summer of 1928, Dr. Hunter observed carp in Lake Erie and its tributary waters and found only one parasitized carp. Professor Struthers found in Owasco Lake, during the month of October, that about one thousand carp had died very suddenly. He was not notified until the carp had been dead for some time, so that it was impossible to determine the cause. It was probably an epidemic. A similar condition was recently noted in Cayuga Lake. This general absence of parasites seems to be another illustration of an animal having left in Europe the intermediate hosts so necessary to the completion of the life-cycles of the parasites.

The most extensive account of disease of carp in American waters is by Dr. Thompson,[9] who believes that he has a definite instance of rickets and that the disease is evident from the fingerling stage throughout life. This malformation is closely associated with the presence of an increase of the sewage load of the Illinois River in the years 1916–18. The carp living in the greatly polluted water showed a retardation of growth. The carp control students have made similar observations on the effect of polluted waters. Young carp taken from the outlet of Onondaga Lake are only six inches long at the end of the first year. This is a marked retardation of growth as compared with those taken in non-polluted waters, where their length is about nine inches and the body much heavier.

It is interesting to compare the conditions of the carp in our American waters with those found in European and Chinese waters. Dr. J. T. Nichols, who has made an extensive study of the Chinese carp, has told the writers in a personal conference that the Chinese carp were subject to a large number of diseases and parasites. A similar condition is evident in the European carp.[10] How long will it be before this primitive bony fish repeats in our American waters its European and Asiatic history?

[7] H. B. Ward, "The Distribution and Frequency of Animal Parasites and Parasitic Diseases in North American Fresh-Water Fishes," *Trans. Am. Fish Soc.*, 41: 207. 1912.

[8] H. E. Essex and G. W. Hunter III, "A Biological Study of Fish Parasites from the Central States," *Trans. Ill. State Academy Sci.*, Vol. 19. 1926.

[9] D. H. Thompson, "The 'Knothead' Carp of the Illinois River," *Nat. Hist. Survey Ill.*, 17: 285. 1928.

[10] B. Hofer, "Handbuch der Fischkrankheiten." München, 1904.

M. Plehn, "Praktikum der Fischkrankheiten," in H. Dennell and H. N. Maier, "Das Handbuch der Binnenfischerei Mitteleuropas." Stuttgart, 1924. Bd. I, pp. 301–470.

NOTABLE PROGRESS IN SURVEYING INSTRUMENTS

By Dr. WILLIAM BOWIE

CHIEF, DIVISION OF GEODESY, U. S. COAST AND GEODETIC SURVEY

A SHORT time ago my attention was called to a very interesting book, entitled "Geodeasia: or, the Art of Surveying and Measuring of Land Made Easie" by John Love, printed in London in 1688. The author, in the first sentence of his "Preface to the Reader" asks, "What would be more ridiculous, than for me to go about to Praise an Art that all Mankind know they can not live Peaceably without?"

He then shows how surveying originated in Egypt where it was necessary to recover boundary marks of private property after overflows of the Nile which covered with mud the indications of the divisions of private property. From Egypt the art of surveying was taken into Greece and, no doubt, from that country was carried all around the Mediterranean region. The last part of Love's preface is of particular interest and significance as it is, in a sense, the inspiration of this paper. The author of the book says:

> I have taken example from Mr. *Holwell* to make the Table of *Sines* and *Tangents*, but to every Fifth Minute, that being nigh enough in all sense and reason for the Surveyor's Use; for there is no Man, with the best instrument that was every yet made, can take an Angle in the Field nigher, if so nigh, as to Five Minutes.

It seems incredible that the surveying art had not progressed beyond the ability of an engineer to measure an angle in the field with an accuracy greater than five minutes less than 250 years ago. To-day we have direction theodolites, read by micrometer microscopes to single seconds, which give closing errors of triangles in first-order triangulation averaging about 1″. The probable error of a direction resulting from the adjustment of an arc of triangulation of first-order is seldom greater than 0″.5.

The development of surveying instruments has really been due to the astronomers. They desired to make observations on the sun, moon, planets and their satellites, and on the stars, and, in order that the work might be done with satisfactory accuracy, they paid much attention to the development of the telescope.

In an article on the telescope by H. Dennis Taylor in the Encyclopaedia Britannica is the following statement:

> But it is quite certain that previous to 1600 the telescope was unknown, except possibly to individuals who failed to see its practical importance, and who confined its use to "curious practices" or to demonstrations or "natural magic." The practical discovery of the instrument was certainly made in Holland about 1608, but the credit of the original invention has been claimed on behalf of three individuals, Hans Lippershey and Zacharias Jansen, spectacle-makers in Middelburg, and James Metius of Alkmaar (brother of Adrian Metius the mathematician).

It is undoubtedly true that the use of the telescope by Galileo brought it into general use in astronomy. While he was not the inventor of the telescope, he must be given much credit for making its use popular.

Prior to the use of the telescope, surveying instruments had pointers or sights on them somewhat like the sights used on firearms. These, necessarily, were coarse and made it impossible to secure angle measurements of a high degree of accuracy. The telescope could not be used in making accurate observations, in either astronomy or surveying, until cross wires or lines etched on glass

were used in the common focus of the eyepiece and the objective. Various attempts were made to improve the telescope in order to measure diameters of small objects seen in the telescope. In an article in the Encyclopaedia Britannica, under the subject micrometer, Sir David Gill states that

It became, in fact, essential to invent a "micrometer" for measuring the small angles which were thus for the first time rendered sensible. There is now no doubt that William Gascoigne, a young gentleman of Yorkshire, was the first inventor of the micrometer. William Crabtree, a friend of his, taking a journey to Yorkshire in 1639 to see Gascoigne, writes thus to his friend Jeremiah Horrocks. "The first thing Mr. Gascoigne showed me was a large telescope amplified and adorned with inventions of his own, whereby he can take the diameters of the sun and moon, or any small angle in the heavens or upon the earth, most exactly through the glass, to a second."

This letter, apparently, was the first written account of the micrometer, but there must have been rather rapid development shortly after this. In the same article is the statement:

The Marquis Malvasia in his "Ephemerides" (Bologna, 1662) described a micrometer of his own invention. At the focus of his telescope he placed fine silver wires at right angles to each other which, by their intersection, formed a network of small squares.

The date 1662 is only twenty-six years before the publication of Love's book "Geodaesia." Apparently the telescope with cross wires had not been applied to the surveying instruments in England when Love's book was published. It would seem, though, that the telescope was employed in surveying work not many years later by J. and D. Cassini between 1683 and 1716 in measuring, by triangulation, a meridional arc of 8° 35′ extending north and south through Paris. It is evident that a telescope with cross wires was used by the Cassinis, for, otherwise, it would have been impracticable for them to execute triangulation of the degree of accuracy which was obtained on the Paris arc.

Early in the seventeenth century Willebrord Snell (occasionally called Snellius) made a great advance over the methods used by his predecessors by introducing trigonometrical methods in the measurement of distances across country. He was really the originator of triangulation, which is now the universally employed method in surveying and mapping large areas. He published a book in Leyden describing his work in 1617.

In observing the angles of the triangles of his arc he used a quadrant of a circle of about two feet in radius. This was graduated to two minutes and readings were estimated to single minutes.

In 1669 Picard began his arc measurement, which was one of the most famous in the history of measurements, to determine the length of a degree of latitude. His work was done more accurately than previous measurements, both because he used a longer base line and because, judging from the best evidence available, he seems to have been the first geodesist who used spider-wires in the telescope attached to his quadrant. His quadrant had a radius of thirty-eight inches and was graduated to single minutes. The quadrant had two telescopes, one fixed and the other movable.

In measuring the angles with the quadrant, it appears that the plane of the quadrant was placed in the plane of the observer and of the two objects to be observed on. This resulted in the determination of the inclined angle. Butterfield in his book entitled "The Figure of the Earth from Arc Measurements" makes the statement: "Picard's measurement as a whole was a step far in advance and may be said to be the starting-point for accurate determinations."

During the latter part of the seventeenth century the Cassini brothers began the extension northward of Picard's triangulation. The work was inter-

rupted but taken up again early in the eighteenth century. The triangulation was extended southward to Spain. Base lines were measured for the control of the lengths of the triangle sides. On their work they used a quadrant of thirty-nine inches radius. This was graduated to minutes and observations were made with two telescopes, one fixed and the other movable.

In determining the latitudes of the stations whose distances apart were measured by the triangulation, an instrument was used which had an arc of a circle ten feet in radius. This arc was twenty-six degrees in extent and was graduated to degrees and minutes.

The next important development in triangulation came with the measurement of the arcs of meridians in Lapland and Peru. The work on these arcs began about 1735. It would seem that at this time an improvement was made in the triangulation method by measuring the differences in elevation of the various triangulation stations which made it possible to compute corrections to the observed angles to reduce them to the horizontal plane.

These attempts to determine the lengths of degrees of latitude by triangulation methods had really no bearing on surveying and mapping at the time that they were made. The work was for scientific purposes only, but the knowledge gained in the attempts to measure long distances across the earth's surface was later used in surveying and mapping. The modern map and chart maker is, therefore, deeply indebted to these great pioneers in earth sciences who attempted to determine the length of a degree of latitude at different places and from that to derive the dimensions of the earth.

From what has been said above it can readily be realized that the instruments used in surveying property boundary lines at the time that Love wrote his book in 1686 were very crude affairs. Probably the compass with pointers similar to the Jacob's staff of a generation ago was the most accurate of the instruments employed.

The biggest step forward which was made in surveying methods was the designing and construction of a theodolite by Ramsden about 1787 while he was engaged on the English end of an arc of triangulation which was to connect the observatories of Paris, France, and Greenwich, England. For the first time it was possible to measure horizontal angles, therefore spherical angles involved in a triangle were obtained and the spherical excess could be applied before making the trigonometrical computations. Ramsden's theodolite was first called a direction instrument. A few years later the French observers designed a repeating theodolite. It is rather noteworthy that the French have since been partial to the use of repeating instruments in their triangulation while the English have clung to the direction instrument.

The horizontal circle of the Ramsden instrument was three feet in diameter; it was graduated to ten minutes and the position of the telescope at any pointing was read by micrometer microscopes to single seconds. Very little improvement in the design of theodolites has been made since this wonderful instrument was designed by Ramsden and made under his direction. The fundamental principles involved in that instrument are practically the same as those in the instruments of to-day. Of course there have been improvements, the most noteworthy being the perfection of graduation of theodolite circles. It is said that the first dividing engine was made in 1740. Probably it was a crude affair as compared with the wonderful machines used to-day. While formerly it was considered necessary to have a very large horizontal circle on theodolites in

order to provide a fair degree of accuracy in the graduations, to-day on the highest order of triangulation, circles eight to ten inches in diameter are considered large enough. In fact, the graduations on circles of the Wild and the Zeiss theodolites are made on glass circles only five inches in diameter. Remarkable results are obtained with these instruments.

In the United States, triangulation was begun by Hassler, who was appointed in 1816 the first superintendent of the Coast Survey (the designation was changed to Coast and Geodetic Survey in 1878). In 1811 Hassler had been commissioned by President Jefferson to travel abroad in Europe to contract for the purchase and supervise the construction of surveying apparatus. While there he visited geographic and surveying organizations in order to become familiar with the best practices and instruments employed in surveying, mapping and charting. Hassler was a great man and far ahead of his time, for he initiated methods for charting the coast which were considered extravagant and uncalled for by most engineers of his time. He asserted that the coast charting should be based on triangulation and he even foresaw the time when the property values in this country would be so great as to justify the cost of extending triangulation over its vast interior.

Hassler brought back from Europe the most modern surveying and astronomical instruments and he employed them on the surveys of the coast which he initiated. It is rather remarkable that the triangulation done by Hassler beginning in 1816 is now, 110 years later, considered standard in accuracy. None of Hassler's triangulation has been discarded because of crudeness or inaccuracy.

With the development of theodolites for use in triangulation in connection with arc measures for the determination of the shape and size of the earth and for connecting astronomic observatories, instruments based on the principle of the theodolite were made also for surveying purposes. To-day the compass is used only in the crudest surveying. The transit, which is a simplified theodolite, is used in all surveying for property lines and for engineering operations.

From the very crude measurements in the triangulation by Snell in 1615, we have now come to triangulation of almost incredible accuracy. The angles of the first-order triangulation of the United States are measured with an accuracy which gives an average closing error of a triangle of only about 1″. The maximum allowable error in the closure of a first-order triangle is about 3″. The closing eror of a triangle is the difference between the sum of the three measured angles and 180° plus the spherical excess of the triangle. The smallness of these errors may be visualized if we consider that the two sides of an angle of one second diverge only one foot at a distance of forty miles from the apex of the angle.

The Coast and Geodetic Survey has executed thousands of miles of arcs of triangulation in the United States for the control of property boundaries, engineering operations and topographic maps. In the recent readjustment of the arcs in the western half of the country into a single network the average closing error of a loop of triangulation was about 1 part in 450,000 of the distance around the loop. There were only two loop closures out of sixteen which were greater than 1 part in 200,000, and the maximum closure was only 1 part in 162,000.

There has been great development in the accuracy of base measurements. In the early days the crudest methods were used, such as counting the turns of a wheel while going from one end of the

base to another. Then came wooden rods, and metal rods of various kinds. Later the surveyor's chain was devised and then came the steel tape, and finally the tape made of the alloy of nickel and iron called invar. The name invar is an abbreviation of the word invariable, used in connection with this alloy because the coefficient of expansion of the alloy is very small. In fact, the change in length of the invar used in the base tapes for a given change in temperature is less than one tenth of the corresponding change for a steel tape.

The most accurate triangulation that has ever been done, as far as the writer is aware, was that in the vicinity of Pasadena, California, executed for the purpose of determining the distance between Mount Wilson and San Antonio Peak, to be used by Professor A. A. Michelson for his determination of the velocity of light. A base line was measured in the valley to the south of the line joining those peaks. The line was more than twenty miles long and the uncertainty in the measured distance between its ends was only 0.14 inch or 1 part in 11,600,000 of the length of the base. This is the probable error of the field measurements of the length. The actual error may have been considerably larger than the accidental error, but, even so, the accuracy of the measurement was very great.

Triangulation was executed to connect the line between Mount Wilson and San Antonio Peak with this base. The greatest precautions were taken during the measurement of the angles, and the deflection of the vertical due to attraction of local mountain masses was determined for each station in order that the horizontal angles measured with the theodolites could be corrected for the tilting of the vertical axis of the instrument. The probable error of the derived distance between the two peaks was 1 part in 6,800,000. It is reasonably certain that the distance furnished Professor Michelson was correct within one part in a million.

This brief sketch indicates that tremendous strides have been made in surveying methods during the past 250 years and that the surveyors and the map and chart makers are deeply indebted to the astronomers, who showed them how to determine latitudes and longitudes on the earth's surface, and to those investigators who wished to know the size of the earth. We have here another striking example of the practical application of the methods used in pure scientific research and the employment of the results for the welfare for humanity.

In preparing this article, the writer has used freely the information contained in various articles in the Encyclopaedia Britannica, in a text-book on "Geodesy and Least Squares" by Charles L. Crandall, and in "The Figure of the Earth from Arc Measurements" by Arthur D. Butterfield. The reader is advised to consult these books if he is interested in following the subject of surveying methods in more detail than is here given.

MATHEMATICAL DESERTS AND SOME OF THEIR OASES

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IT is a somewhat singular fact that the well-known Egyptian work of Ahmes, written about 1700 B. C., opens with a small desert since the operation of expressing rational fractions in terms of the sum of fractions having unity as a common numerator and distinct denominators has not proved to be of much importance, notwithstanding the fact that we find evidences of its use extending over a period of more than three thousand years. An oasis in this desert is due to the fact that this operation simplifies the notation of rational fractions since the only rational numbers which required consideration in this system are the positive integers and their reciprocals. While this work of Ahmes opens with a small desert it should not be inferred that its contents are entirely of this character. On the contrary, it exhibits the elements of the very fertile interplay of analysis and geometry as well as the elements of the fertile use of an operand symbol for the unknown.

The Great Sahara of mathematics is formed by the almost endless variety of the notations employed therein. A fertile oasis in this desert is due to the great value of a good notation and the discrimination involved in its selection. Even the numerical notations which have been used present a vast amount of material which is almost barren as regards fruitful ideas. In particular, the various notations leading up to our common numerals present little that is thought-inspiring since many of the changes involved therein seem to be due to chance and not to a well-planned general scheme. These notations, are, however, of much greater interest than those employed by many other peoples, such as the Babylonians and Chinese.

A mathematical desert of considerable size has been formed by the philosophical speculations relating to the properties of numbers. This type of speculation has been especially associated with the name of Pythagoras. According to Aristotle the Pythagoreans had a number creed as follows:

(1) Limited and unlimited.
(2) Crooked and straight.
(3) One and many.
(4) Right and left.
(5) Masculine and feminine.
(6) Resting and moving.
(7) Straight and curved.
(8) Light and dark.
(9) Good and evil.
(10) Square and rectangle.

A member of the Pythagorean School, Philolaus, states that "all things which can be known have number; for it is not possible that without number anything can either be conceived or known."

It seems likely that the Pythagorean number speculations were partly due to the fact that the units of area and solids were commonly so selected that their edges are linear units and hence numerical relations were seen to exist between magnitudes of widely different characters. Hence the essence of number seemed to lie much deeper than the outward forms of things. It has also been suggested that the deep interest in numbers on the part of the Pythagoreans was inspired by noting that the constellations of the sky may be characterized by the number of visible stars contained therein. At any rate, many of the philosophical speculations about numbers

have been fruitless as far as direct results are concerned. An oasis in this work is furnished by the interest in the so-called Pythagorean triads. Special cases of these were known to the Babylonians at least as early as 4000 B. C., and their study naturally led to the greater Fermat theorem, which has been the source of much fundamental modern work in number theory as well as of many fruitless endeavors.

The ancient Greek mathematicians entered various other mathematical deserts without realizing that they were deserts. The most noted of these are formed by the three great problems of antiquity, *viz.*, the duplication of the cube, the trisection of a general angle, and the squaring of a circle by means of ruler and compass only. It is now known that the last of these is impossible even by means of the most general algebraic constructions while the other two involve the solution of an irreducible cubic equation. Fortunately, their efforts to solve these problems gave rise to a very fruitful study, *viz.*, the study of the conic sections. While exploring these deserts the ancient Greeks incidentally discovered a wonderfully fertile region lying beyond them. They entered this region with great enthusiasm and their wonderful mathematical contributions were crowned by the fruits thereof as is illustrated by work of Apollonius of Perga.

Judging from our modern practices the Greeks entered a mathematical desert even in the noted *Elements* of Euclid where curvilineal as well as rectilineal angles are considered and it is proved that the horn-like angle, *i.e.*, the angle at the point of contact between a circle and a tangent to it, is less than any rectilineal angle. They were thus led to absolutely infinitely small magnitudes since such magnitudes are presented by the differences between the angles at the point of contact formed by different circles which have a common tangent line. Fruitless discussions relating to these horn-like angles were continued during many centuries. An oasis of these discussions is that they exhibit the usefulness of the postulate that all right angles are equal and that they directed attention to a fundamental question in the calculus. It would be difficult to find a more instructive illustration of the nature and usefulness of postulates than the one furnished by the pencil of circles noted above which are supposed to make equal angles with their common diametral line. Instead of saying merely that axioms are self-evident truths, it should also be noted that they may serve to blindfold us, as here, with respect to truths which appear unnecessary for the work in hand.

The mathematical deserts to which we have referred suggest some analogies between the study of mathematics and the cultivation of the soil. Various unusually fertile regions for mathematical study were developed from time to time, and for many centuries students have derived much pleasure and profit from their cultivation. In many cases this cultivation was continued along the lines originally suggested while in other cases there have been radical changes in the methods. Weeds in the form of errors seem to grow up spontaneously in these fields of mathematical study, and most of them can be kept under control by cultivating for the regular crops, but sometimes it seems desirable to devote especial attention to the extermination of weeds. Naturally such a subject as the history of mathematics is especially subject to weeds and hence there is more need of error extermination here than in most of the other subjects. It would be as unwise for the mathematicians to devote all their time to the eradication of error as it would be for the farmers to devote all their time to the extermination of weeds. On the other hand, scien-

tific honesty compels us to use the term weeds for actual weeds irrespective of where they may be growing.

Just as parts of the deserts of the earth have been reclaimed by the construction of irrigation works since very ancient times so parts of the mathematical deserts have been transformed into fertile fields by the construction of ideal elements. As conspicuous examples of such elements we may mention the ordinary complex numbers and the point at infinity. In fact, all pure mathematics may be said to be based upon ideal elements since even the abstract integers are the work of man. Hence the common statement—"God made the integer; all the rest is the work of man"—can not be regarded as literally true. From this it results that all pure mathematics may be regarded as being based upon ideal elements and hence all of it would be a desert if these ideal elements had not been constructed. Some of these ideal elements, such as natural abstract numbers, were constructed in prehistoric times and the fertile regions based thereon may therefore have the appearance of being natural.

The noted German mathematical historian, M. Cantor, in an address before the Paris Congress of Mathematicians, held in 1900, passed over the works of a large number of authors with the following significant remark: "Tous aussi morts que leurs livres; gardons-nous de les ressusciter." A real danger of science is that it will be overwhelmed by its bulkiness and one of the greatest needs of our times is discriminating forgetfulness in accord with this quotation. It is true that even the most discriminating forgetfulness will sometimes entail some loss, but such losses are more than compensated for by the decrease in bulk. In particular, there are hundreds of elementary text-books which make no contribution to knowledge and which should not be allowed to waste the time of all later students of the history of our subject. Complete bibliographies are usually much less valuable than those which include only such works as contributed to the advancement of the subject concerned, but the latter make greater demands on the scholarship of their authors.

Let us be careful not to revive the dead is a note of warning which is perhaps especially needed now in view of the growing interest in the history of science. The rapidly growing richness of this history makes it more and more necessary to select only the best for presentation in a general text-book devoted thereto but it increases the temptation to become bulky. One of the most striking recent discoveries in mathematical history is that the ancient Egyptians used the very fundamental theorem in geometry that the area of a sphere is equal to that of four of its great circles, but they apparently had no proof thereof. It seems therefore probable that this theorem was assumed to be true more than fifteen hundred years before it was proved by Archimedes and thus endowed with much greater intellectual richness. Such discoveries tend to explain why the ancient Greeks went to Egypt and Babylon for their mathematical inspiration.

Mathematical explorations were never pushed with more energy than at present, and it is only reasonable to expect that in the future some of these will be regarded as relating to deserts. As in the past it is to be hoped that in some cases these will be extended beyond the deserts and disclose regions of great fertility while others will probably be abandoned and be remembered only in the history of our subject. Notwithstanding these occasional deserts which have not been reclaimed by irrigation the developments in mathematics stand before us to-day as a great and useful intellectual achievement which gives promise of being greatly extended and of becoming

much more useful. The ancient Greeks seem to have been the first to convert this achievement into real intellectual food by means of demonstrations but earlier people recognized its utility and must have been charmed by such elegant theorems as the one noted above with respect to the area of a sphere.

As far as we know now the pre-Grecian period of mathematical development was one in which little attention was given to proofs and in which only rational numbers were considered. Hence this early mathematics was mainly a mathematics of the desert, and its outstanding developments seem to have been due to the Egyptians and the Sumerians. The ideal element of abstract rational number was introduced during this period, and problems involving the quadratic equation and the use of the Pythagorean theorem were solved. The crowning work of this period seems to have been the recently discovered rules for finding the volume of the frustum of a square pyramid and the area of a sphere. The Greeks introduced a very fruitful ideal element in the form of the irrational and they laid especial stress on proofs, which made it necessary for them to construct systems of postulates. Their mathematics thus become most fruitful and a model for scientific endeavor extending through more than two thousand years. The fact that they entered into some desert regions is of interest, but it should not blind us to the fact that they also developed very fruitful regions so that mathematics is even now sometimes called a Greek science.

THE CONFLICT OF THE PSYCHOLOGIES

By PROFESSOR JOSEPH JASTROW

THE acceptance of psychology in the confederation of the sciences is accomplished. But an internal warfare continues which in historical circumstance is unfortunate and in professional responsibility scandalous. There is no parallel elsewhere. If physicists, chemists or biologists spent as much futile argument in discussing the purposes of their science and held as antagonistic views of the fundamental concepts and direction of progress, that progress itself would be just so far hampered. The state of affairs is not without justification. When the object of research involves the researcher himself, cross lights are inevitable. One is reminded of the myth that Socrates was so strabismic or so introverted as well as so flat-nosed that, in his passion for self-analysis, he trained one eye to look into the other, thus carrying introspection to its experimental extreme. The salvation of all science is its extraverted objectivity—its conviction that things are so regardless of our peculiar insights or outlooks. "Know thyself" may have been a precept in the objective temper; if so, it was promptly counteracted by the subjective presumption: "Man is the measure of all things." Presumably a psychological congress in ancient Athens would have had no more resemblance to a peace conference than a modern one, despite our increasing knowledge of human relations.

It may not be amiss to rehearse the stages by which modern psychology was made possible. In Freudian version the story would be one of decentralizing or deflating the human ego. In the beginning was a superiority complex. Man regarded himself as the center of the universe; a planet that held so noble a creature could be no less than the pivot about which the sun and the cosmos turned. Copernicus and his followers inflicted a harsh blow upon man's planetary dignity; and "*e pur si muove*" has always had to be uttered with hushed breath. When capable of reflection, man sought his future in the impressive stars; nothing was too vast to serve as a medium or a herald of his fate. When the sun no longer rose and set in his honor, he developed the astrological consolation. By the like presumption he made himself the lord of creation, and created gods in his own image. He elevated to the place of consideration that part of his nature that was quite properly his supreme heritage, his immortal soul; he fantasied a paradise for it in the past, a heaven in the future, and from the outset and continuously fell into the hands of the medicine-man who filled his mind with magical ceremonies and glorified mysteries for which the earthly realities were but vicarious or symbolic pathways.

In due course, as truth penetrated despite the resistance offered by the primal urge to self-importance, man's cosmic ego received one traumatic shock after another. He discovered that he was living in one of the minor planets, and that even these did not move in what he regarded as the perfect orbit of the circle, symbolizing his own perfection, but gyrated in such degenerate *Gestalts* as ellipses. He discovered or suspected that the world did not begin with his own creation, but that life, not so dissimilar to his own, preceded it by many eons. The insult of geology and biology was added to the injury of astronomy. His superiority complex suffered under the successive revelations of his insignificance. Evolution inflicted the most unkindest cut of all, the resentment continuing to this day in the fundamentalism of the American wilderness. He had to accept

the genealogy of his anthropoid kin. But through it all, especially in the high seats of academic learning, he clung with tenacity to his philosophical dignities. And if he was declared an apish biped without feathers, he still plumed himself upon the exclusive integrity and unique distinction of his clamorous soul. In his psychological ark, which was to ride high and dry above the scientific inundations, he assembled the instincts in graded animal array, but reserved to himself the gift of reason. His moral urge to perfectionism stood by him. Throughout the ages of shifting darkness and light, he sought the compensations of religion and philosophy, and cultivated the defense mechanisms of morality. He was determined to save his psyche at all costs from the degradations of nature. The supernatural, the mystically natural, the philosophically overnatural, held the stage in turn, and jointly. The last, by its command of the instruments of learning, became the most enduring citadel. There could be no psychology in our modern sense until this slow process of disillusionment was completed.

There are more reasons than this why psychology was late in appearance upon the scientific scene; yet part of the delay resulted from the persistent conflict between the resistance to what was regarded as a mechanistic degradation and the cherished self-determining glorification of human dignity, more and more centrally symbolized by man's reasoning, moralized, possibly immortal soul. In altered temper the conflict continues. The extreme behaviorist insists that the cosmopolitan human herds diving hurriedly into subways and emerging restlessly into skyscrapers are as readily intelligible in their gyrating responses as are rats in a maze seeking what they may devour; while the Freudian analysts maintain that there is no slightest gesture in all this locomotor perturbation that is not complexly animated by vestiges of motives as primal as the sex-ridden cave-man, and as complicated as the urge to security and completion that accounts for the maze-like patterns of civilization.

But it is high time that we should realize that we have fully awakened from this psychological dream. When we pass from its latent meaning thus portrayed in sub-self motives to its patent incidents of plot and circumstance, we find ourselves in a different world alike of interest and of vocabulary. I shall be bold enough to give my own solution first, for I am convinced that all psychology is one no less than is physics or biology, and that the conflicts of the psychologies, so confusing to child study associations, editors of popular magazines, backwater professors of education and the inquisitive laity generally, and likewise so dear to cultist devotees within and without the profession—that this appearance of hopeless division is for the most part illusory, and can be resolved as readily as the famous contradictory description of the elephant by the blind men, one of whom had him by the ears, another by the tail, another by the leg, another by the trunk, and none saw him rightly or whole for lack of eyes to see. For the structural and the functional, the dynamic and the purposive, the introspective and the experimental, the behaviorist and the Freudian, the Gestaltist and the self-psychologist and the other "ism" renderings of the field of mind, are all partial gropings to describe the same beast, as nature made him, and as those whose psychological organs of vision are fully opened can readily see him.

It is obvious to the point of a truism that there is only one psychology, and my stock answer to the persistent inquiry as to what brand of psychology I profess is *naturalistic* psychology. In common with every other psychologist I am a student of human nature, and my first and last obligation is to see that nature as nature made it, and as man has remade it for his own purposes; for that

remaking and that comprehension is the true human glory. The rest is a matter of emphasis, dominance of interest and detail of interpretation. I am convinced that despite their special allegiances the great majority of active psychologists are naturalistic psychologists, and would be willing so to enroll themselves. Science advances not by way of isms but by clarification of concepts. The shifting concept of the human psyche is the core of the history of psychology. The naturalistic concept is established, and thereby sets the course of present-day and all future pursuits.

Still viewing the prospect from our privileged position of clarity and unity, psychology is seen to be the study of the motives and mechanisms of behavior and their organization, and it was never anything else, however mistakenly through presumption or prejudice these motives and mechanisms were misread. The precisionist will insist upon the insertion of the word "mental" before "behavior," and thereby precipitate the unavoidable issue. Unfortunately, the term consciousness became entangled with the ancient dignities as well as with the intraverted strabismic attitude called introspection (from which Professor Bentley vainly wishes to remove the curse by calling it inspection). It still requires a drastic correctional operation to make it plain that this self-awareness is as naturalistic a function as any other. It is in nature's program, and is embedded deep in the evolution of the nervous system. A simple recognition of this naturalization of cerebral function in terms of awareness and all its implications appears in Professor C. Judson Herrick's "The Thinking Machine"—a recent biological version of the essentially human type of behavior. He speaks of the organs of consciousness as readily as of the organs of digestion or the organs of sex, and recognizes in the interplay of those mechanisms the impediments of behavior that may ensue if digestion or sex intrude too constantly upon the domain of consciousness. He makes it plain that without the awareness function, the specifically human gradient of behavior would not have arrived. Consciousness in all its varieties, including subconsciousness and simple orders of sensibility, finds its place in the naturalistic series.

The actual struggle for the establishment of psychology is accordingly the conflict between the pre-naturalistic or anti-naturalistic or super-naturalistic positions versus the naturalistic psychology that has been in the making since Darwin, though it presents previous to that critical era quite an interesting group of antecedents in the story which Baldwin, Dessoir, Brett, Stratton and more recently Gardiner Murphy have presented, and which might well be represented from the approach which I have emphasized. The modern psychologist would be aided and his presumption in turn chastened if he acquired a more intimate historical sense of the story of his profession.

How magical-mystical psychology gave way to a rationalistic view of the human psyche, and how variously it survived and survives, is a tale of significance that runs somewhat parallel and somewhat tangential to the central development with which the historical texts deal. Unfortunately, what is academically central is often not so in the larger view of human interests. Chapter upon chapter must be devoted to the intensive (though to our interests often irrelevant) pursuit of questions of psychological bearing considered in a religious, moralistic and philosophical temper, which for so long made psychology but a subordinate protectorate of philosophy, and infused into it quite alien interests, quite misleading interpretations. The story of all science is full of irrelevancies and false leads, but none perhaps more so than the story of psychology.

The naturalistic psychologist is as prepared as is Watson to reject every vestige of the older approach, but reminds that insurgent behaviorist that this ancient war is over; that there is no purpose in throwing stones at the windows of already deserted houses, however strong the temptation to the small boy that survives even in dignified psychologists.

The other errors of behaviorism à la Watson are more interesting, though perhaps important only in so far as it is more difficult to evolve truth out of confusion than out of error. Evidently we are all behaviorists, but how we interpret our behavioristic obligations may determine largely the trend of our psychological interests. I regret that I may seem to be doing extreme behaviorism too much honor in singling out its extravagances for mention, but it is a fact that this petulant challenge has served the purpose of making responsible psychologists examine their fences and revise their stakes and claims. The dominant and wholesome effect of the naturalistic concept of mind was to divert the overattention to the dignities and lordly prerogatives of the human soul toward the humbler examination of man's communities with the rest of creation and of the simpler beginnings of his mental life. The genetic approach and the broadly zoological approach proved to be variously helpful to naturalistic psychology; so did the physiological approach, demonstrating the organic dependence of so-called higher functions. All this activity, which more than anything else characterizes the modern temper in psychology, has as its central direction the study of psychology from below, of the simpler functions and integrations. The emphasis upon child behavior, upon animal behavior, upon physiological behavior in its psychological integration, is all one consistent expression of the supremely important principle that the simpler, earlier, more intimately organic approach is the indispensable clue to all the varieties of emergent superior functions that equip us to behave like human beings and to misbehave according to the same patterns. It was natural and helpful that with the specialization of psychology, owing to its imperialistic expansion in the last generation, there should be those to whom this "primitive" psychology would make the largest appeal. Taking their clue from the reflexes which form the action pattern of primitive response, some have proposed the name of reflexology, or again, objective psychology, for this domain. I see no worthy purpose in giving this division of naturalistic psychology a special brand. If we continue in that direction we may have to recognize tropismic psychologists and thalamic or visceral psychologists as well as cortical or neo-palliumistic psychologists; and though we shall enrich our vocabulary we shall impoverish our co-operation.

To conclude that because this "primitive" gradient underlies the whole of our psychic life, therefore its pattern dominates the whole of psychology is an error of the first magnitude. Dr. Watson's invitation to psychology to commit hari-kari under his assurance that the psychologist has no insides to speak of must be politely declined. The conditioned reflex though real is most limited, and the problem of the true behaviorist is to explain how we develop our intelligence by remaining so largely free from conditioning. That the proper appreciation of our "primitive" psychology required an emancipation from the fallacies of our introspective dignities I have made clear; but the transformation of that emancipation into an "ism" is responsible for much of the fallacious appearance of the conflict of our psychologies. Dr. Watson's dramatic execution of consciousness reminds one of Mark Twain's similar response to a similar "religious" stimulus.

Having listened under durance to a sermon on the God-given nature of conscience and the high privileges of that endowment, this skeptical penitent decided that he was much too frail a creature to undergo so severe a strain; so he took his conscience down cellar and killed it with a hatchet. The similar destruction of imagery, of heredity, of insanity, I must on the present occasion decline to take too seriously. I am considering behaviorism and not Watsonian idiosyncrasies. My purpose is accomplished if I can make plain that extreme behaviorism is a radicalistic reaction to the neglect of primitive psychology, and is thus partly responsible for the fallacious conflict of the psychologies.

We may interpret Freudianism as a similar overstatement of cortical psychology to put it neurologically, of spiritual psychology, to put it historically. It is no longer the primitive fear and wonder of our make-up, but a far more sophisticated and perhaps equally strabismic and certainly more harrowing soul introspection that appears in psychoanalysis. A Socratic Freud would be represented as an introverted oversoul suffering from a complex, peering into the subsoul that from its place of repression in the nether regions looks and answers back. Yet the Freudian may claim that such is nature; the only difficulty is to prove it. Its naturalistic intention may be admitted. Observe also how closely these tendencies, and as subconsciously as the complexes which it discovers, turn about those two pivotal phases of the human psyche, its motives and its mechanisms. Freudian psychology is motivation psychology, or motivationism as Troland properly calls this approach; and it discovers its mechanisms in the motivistic temper. So once again, though all psychologists deal with motives and mechanisms, some are primarily motivationists, others primarily mechanists. The behaviorist proposes one set of mechanisms, the Freudian another; and they are not farther apart than are the gradients of the application. What at the one level is called the conditioned response is at the other called (psychic) fixation. We may have brain-stem conditionings and cortical fixations. So far as they validly describe psychic integrations, they are naturalistic.

Again we are fortunate in that as a result of the experimental advances we have come upon an aid to the resolution of this conflict between psychology from below and psychology from above. For we have established a glandular psychology, and have found in its intimate correlation with autonomic functions that nature herself supplies the resolution of the conflict. We are provided with two nervous systems and not one, both alike nature-set; and as we are autonomists or neo-pallic devotees, we shall emphasize our glandular bondage or our cortical self-determination. The danger in assimilating the insight is that of going beyond the evidence. We may be safe in speaking of a hyper-thyroid personality; but if we go on to say that President Harding gave us an adrenal administration and President Wilson a pituitary one, we endanger the quality of our psychological as well as our political affiliations. Naturalistic psychology likewise has its temptations.

And what about the Gestaltist? He is equally naturalistic and turns to the nature-set patterns of behavior for the interpreting concepts of his system. He has introduced a valuable correction of the stimulus-response formula applicable to a wide range of behavior. He has even ventured to find in the analogues of physical constitution a questionable support of his configuration principles. Gestaltung is organization, which in turn is an emphasis upon the total organism affected by the total situation and its total meaning; it is a protest against the detached analyses of an out-

grown psychology. Organization extends from the lowest to the highest. It is inherent in this view to seek the supporting data in the natural range of behavior from low to high, alike in the ascending development of the infantile to the mature, and in the simplest and more rigidly patterned insect behavior to the occasionally rational chimpanzee and the frequently irrational human responses. The Gestaltist has been sanely rational in his claims and on good terms with his colleagues. Repeating the proffered definition of psychology as the study of the mechanisms and motives of behavior and their organization, the Gestalt psychology centers upon the organization.

The menace of the conflicting psychologies is that each will lay claim to the jurisdiction of the whole. By recognizing their common cause in a naturalistic interpretation, the conflict disappears. The day of isms is past; the history of isms is unfortunate. Psychology has come to its own by the same irregular dispensation by which the human mind has found itself, through the outgrowing of the presumptions and the errors of the ages. The story of psychology finds its reflection in the story of each of the sciences. But the unique fact that in this instance the instrument of enlightenment is also the object of study makes the story of man centrally the story of his psychological emancipation.

THE PREEMINENCE OF PRIMARY EXPERIENCE

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JOHN LOCKE, the leading English philosopher of the seventeenth century, affirmed his belief in the ancient dictum, "There is nothing in mind which was not first in the senses," to which his contemporary, Leibnitz, the eminent German philosopher, retorted: "Except the mind itself." In condemning Leibnitz's doctrine of innate ideas which restated Plato's theory that certain universal ideas were part of the original nature of the new-born child, Locke fostered the opposite doctrine that its mind was a blank tablet, and received sensory impressions from the sense organs as materially as the Roman wax tablet received the strokes from the stylus. Put in modern terms, this theory means that mind is changed by sensory stimuli as the film in the kodak is changed when the shutter is opened. Wordsworth, a fellow-countryman of Locke, voiced this static conception of mind in these words:

> The eye—it can not help but see;
> We can not bid the ear be still;
> Our bodies feel, where'er we be,
> Against or with our will.

The modern point of view holds that mind is inherently active and that it selects, from the myriad sensory stimuli ceaselessly impinging upon the sense organs, those particular ones to which it attends. Hence the sensory stimuli arouse activity that is inherent in mind but in no wise create that activity. As a source of initiating mental responses, the direct participation in life activities, or primary experience, is infinitely more valuable than the memorization of words describing such activities. The following paragraphs propose to illustrate the preeminence of primary experience.

Half a century ago, the late G. Stanley Hall made a study of "The Contents of Children's Minds on Entering School." The results revealed a woeful ignorance of the commonest things. Superintendent Greenwood found similar conditions prevailing among the young children in the schools of Kansas City. Teachers of young children were therefore admonished to take nothing for granted and examine critically the meanings which children attached to their words. Out of the fullness of his experience in a long active life, the late President Eliot wrote:

> It is a matter of everyday experience that most Americans can not observe with accuracy, repeat correctly a conversation, describe accurately what they have seen or heard, or write out on the spot a correct account of a transaction they have just witnessed. . . .
>
> The most important part of education has always been the training of the senses, through which the best part of knowledge comes. This training has two precious results in the individual besides the faculty of accurate observation—one, the acquisition of some sort of skill; the other, the habit of careful reflection and measured reasoning which results in precise statement and record. . . . It follows from these considerations that the teaching of the senses should always have been a prime object in human education at every stage from primary to professional. That prime object it has never been, and is not to-day. The kind of education the modern world has inherited from ancient times is based chiefly on literature.

The ancient Greek ideal of the educated man was "the speaker of words and the doer of deeds." Though the schools gave music for the soul and gymnastics for the body, there were many other educative forces at work developing youth. The great athletic games, the dramatic contests and the

participation in the social and political life of the day secured a harmonious development of the acting, feeling and thinking sides of life attained by no other people.

Since Neo-Platonism taught that the sole source of knowledge came through revelation, the leaders of the Middle Ages withdrew from contact with the world, and hence discouraged the study of nature. With its emphasis on dialectics, scholasticism enforced the verbal memorization of dictations justifying abstract theological dogmas. Absorption in the life to come led to the abhorrence of the beauties of the present world.

Though the Renaissance began as a great liberalizing movement, it soon degenerated into the study of language to the neglect of the message of the literature embodied therein. Since the learner was exalted above the doer, the movement resulted in "gerund-grinding" and the rote-memorization of Latin paradyms. A writer of the time declared: "Youth is deluged with grammar precepts infinitely tedious, perplexed, obscure, and for the most part unprofitable, and that for many years."

As time went on, many educational reformers arose and rebelled against these practices. Rabelais, the French writer, prescribed for Gargantua a wide acquaintance with nature and many constructive activities. His fellow countryman, Montaigne, advocated wide reading of biography, even if it was in Latin, so that youth would come into intimate contact with the great men of antiquity, and wide travel in different countries to learn the customs and traditions of other nations. Then, too, Rousseau, the most brilliant prophet of the eighteenth century, was a firm champion of primary experience. He wrote:

> As everything that enters the mind finds its way through the senses, the first reason of a human being is a reason of sensation; that it is which forms the basis of intellectual reason; our first masters in philosophy are our feet, our hands, our eyes. Substituting books for all this is not teaching us to reason, but simply to use the reason of other people; it teaches us to take a great deal on trust and never to know anything.

Pestalozzi, the Swiss educator, a follower of Rousseau, made the following entry in his diary:

> O God, who art my Father, and the Father of my child, teach me to understand the holy natural laws by which Thou preparest us slowly by means of an innumerable variety of impressions for the conceiving of exact and complete ideas of which words are but the signs. . . . Lead your child out into nature. Teach him on the hill tops and in the valleys. . . . In these hours of freedom, let him be taught by nature. Should a bird sing or an insect hum, at once stop your talk.

The way the child learns from nature is thus described by Whitman:

> There was a child went forth every day,
> And the first object he looked upon that object he became,
> And that object became a part of him for the day or certain part of the day,
> Or for many years or stretching cycle of years.

So the birds and the beasts, the flowers and the fields, the marshes and the hills, and more than all his parents and his friends—

> These became a part of that child who went forth every day.
> And who now goes, and will always go forth every day.

Just as Hiawatha learned of every bird and beast its language and its secrets, so Charles A. Eastman, born in the tepee of a Santee Sioux, learned the woodcraft of his people. Every morning as he "went forth" his uncle would charge him thus:

> "Hadakah, look closely to everything you see." And at evening, on my return he used often to catechise me for an hour or so. "On which side of the trees is the lighter colored bark? On which side do they have the most regular branches?" It was his custom to let me name all the new birds that I had seen during the day. I would name them according

to the color or the shape of the bill or their song or their appearance and the locality of the nest. In fact, anything about the bird that had impressed me as characteristic. He then usually informed me of the correct name. Occasionally I made a hit and this he would warmly commend. He went deeper into this science when I was a little older. He did not expect a correct reply at once to all the voluminous questions that he put to me on these occasions, but he meant to make me observant and a good student of nature.

In a similar way, country children of the last century learned important bits of information incidentally in their everyday experiences. Thus S. S. Goodrich, better known as Peter Parley, compiler of some eighty school texts, secured the best part of his education.

In my youth, I became familiar with every bird common to the country; I knew his call, his song, his hue, his food, his habits; I could detect him by his flight as far as the eye could reach. I knew all the quadrupeds, wild as well as tame. I was acquainted with almost every tree, shrub, bush and flower indigenous to the country. When I have traveled in other countries, the birds, the animals, the vegetation have interested me. In looking over the pages of scientific works on natural history, I have always read with eagerness. Every idea I had touching these matters was living and sympathetic, and beckoned other ideas to it, and these again originated still others. Thus it is that in the race of a busy life, by means of a homely, hearty start, I have, as to these subjects, easily and naturally supplied, in some humble degree, the defects of my irregular education.

Reference may be made here to the effect of nature on the lives and works of a number of the great poets. Alive to every wonder of field and forest, Shakespeare noted carefully "the temple-haunting martlet," "the strange fowl" alighting on "neighbouring ponds," or "the banks whereon the wild thyme grows." Thus he could boast even in boyhood,

In nature's infinite book of secrecy
A little can I read.

Blest with genius and a wonderfully rich sensory experience in youth, he was able in manhood to weave them into his imperishable dramas. The clear word pictures in these lines reveal the vividness of sensory images gleaned from wide acquaintance with the flora in springtime.

When daisies pied and violets blue
  And lady-smocks all silver-white
And cuckoo-buds of yellow hue
  Do paint the meadows with delight.

It is little wonder that Wordsworth became the harbinger of the nature poets. Born in the small village of Cumberland, he spent his boyhood in the wonderful Lake District where his mind was thrilled with its beauty. His earliest recollections were of the grassy holms and rocky falls of Derwent, and the towering form of Skiddaw. His school days were passed on the banks of Esthwaite Water. What more could be asked in scenic splendor? His appreciation of natural beauty is contrasted with that of the traditional schools as expressed in "Exposition and Reply," where the master scolds William for dreaming his life away:

Where are your books? that light bequeathed
To beings else forlorn and blind!
Up! Up! and drink the spirit breathed
From dead men to their kind.

In "Tables Turned," William makes answer:

Books! 'tis a dull and endless strife;
Come, hear the woodland linnet,
How sweet his music! On my life
There's more of wisdom in it.

And hark! how the blithe throstle sings!
He, too, is no mean preacher;
Come forth into the light of things,
Let nature be your teacher.

One impulse from a vernal wood
May teach you more of man,
Of moral evil and of good
Than all the sages can.

Though color-blind and with a poor ear for music, it is surprising how accurately Whittier observed and portrayed

the sights and sounds of the farms about Job's Hill. He knew country life intimately as shown in "Snowbound" and "The Bare-Foot Boy":

> Knowledge never learned of schools,
>
> For, eschewing books and tasks,
> Nature answers all he asks.

Fortunately for Emerson, he was raised in "a quiet open region of gardens and pastures, sunny in winter and shady in summer." Of his life at Harvard, which he entered at thirteen, he wrote:

> The boy at college apologizes for not learning the tutor's tasks, and tries to learn them; but stronger nature gives him Otway and Massinger to read, or betrays him into a stroll to Mount Auburn, in study hours. . . . Ah, the powers of the Spring, and ah, the voice of the bluebird and the witchcraft of Mount Auburn dells in those days.

Thus in "Good-bye" he wrote these delightfully refreshing lines:

> O, when I am safe in my sylvan home
> I tread on the pride of Greece and Rome;
> And when I am stretched beneath the pines,
> Where the evening star so holy shines,
> I laugh at the lore and the pride of man,
> At the sophist schools and the learned clan;
> For what are they all, in their high conceit,
> When man in the bush with God may meet?

In "May-Day" also he reveals his keen appreciation of nature's spell:

> If I could put my woods in song
> And tell what's there enjoyed,
> All men would to my garden throng,
> And leave the cities void.
>
> Can'st thou copy in verse one chime
> Of the wood-bell's peal and cry,
> Write in a book the morning's prime,
> Or match with words that tender sky?
>
> Ever the words of the gods resound;
> But the porches of man's ear
> Seldom in this low life's round
> Are unsealed that he may hear.
>
> But the meanings cleave to the lake,
> Can not be carried in book or urn;
> Go thy ways now, come later back,
> On waves, and hedges still they burn.

The early influences of the beauties of nature are clearly shown in the writings of Longfellow. His birthplace, Portland, was a beautiful city full of trees, with the ocean in front, while in the hinterland rose the low hills of Munjoy and Bramhall deeply wooded. In manhood, he wrote:

> Often I think of the beautiful town
> That is seated by the sea;
> Often in thought go up and down
> The pleasant streets of that dear old town,
> And my youth comes back to me.
>
> . . . .
>
> I can see the shadowy lines of its trees,
> And catch, in sudden gleams,
> The sheen of the far surrounding seas,
> And islands that were the Hesperides
> Of all my boyish dreams,
>
> . . . .
>
> I remember the black wharves and the slips,
> And the sea-tides tossing free;
> And Spanish sailors with bearded lips,
> And the beauty and the mystery of the ships,
> And the magic of the sea.
> And the voice of that wayward song
> Is singing and saying still:
> "A boy's will is the wind's will,
> And the thoughts of youth are long,
> long thoughts."

With these ever-recurring voices of youth, it is little wonder that he wrote these fascinating lines on the influence of nature in his poem for the celebration of "The Fiftieth Birthday of Agassiz," the leading naturalist of the time.

> And Nature, the dear old nurse, took
> The child upon her knee,
> Saying: "Here is a story book
> Thy Father has written for thee.
>
> Come wander with me," she said,
> "Into the regions yet untrod;
> And read what is still unread
> In the manuscripts of God."
>
> And he wandered away and away
> With Nature, the dear old nurse,
> Who sang to him night and day
> The rhymes of the universe.
>
> And whenever the way seemed long,
> Or his heart began to fail,
> She would sing a more wonderful song,
> Or tell a more wonderful tale.

From these selections, taken as types, we conclude that the poets believed that contact with nature was an educative force of prime importance. What then is the place of the book? In "The American Scholar," Emerson gives an excellent answer:

> I had better never see a book, than to be warped by its attraction clean out of my own orbit, and made a satellite instead of a system. Hence, instead of Man thinking, we have the bookworm. Hence, the book-learned class, who value books, as such; not related to nature and human constitution, but making a sort of Third Estate with the world and the soul. Man thinking must not be subdued by his instruments. Books are for the scholar's idle times. When he can read God directly, the hour is too precious to be wasted in other men's manuscripts of their readings. But when intervals of darkness come, as come they must, when the sun is hid, and the stars withdraw their shining, we repair to the lamps which were kindled by their ray to guide our steps to the East again, where the dawn is.

Thus to Man thinking, books become the beacons that beckon on to new vistas of adventure. In "Great Naturalists" Henry F. Osborn states the influence of Malthus on Darwin and Wallace. Darwin wrote thus:

> In October, 1838, that is fifteen months after I had begun my systematic inquiry, I happened to read for amusement, "Malthus on Population," and being well prepared to appreciate the struggle for existence which everywhere goes on, it at once struck me that under these circumstances favorable variations would tend to be preserved and unfavorable ones be destroyed. Here, then, I had at last a theory by which to work.

Though he gleaned little benefit from his college work, he profited much from reading Shakespeare, Wordsworth, Coleridge and Milton. He prized greatly the associations with such men as Herschel, Humboldt, Henslow, and above all the great geologist Lyell. The most dominant and dynamic forces of his whole life, however, were the years spent on the voyage of the *Beagle* which fruited twenty-one years later in "The Origin of Species." Wallace had read the same stirring books, and felt the spell of these same scientists. Four years spent along the Amazon, and, later, eight years in the Malay Archipelago, afforded him the materials to bolster up the same theory of evolution which had come to Darwin twenty years earlier. In both cases, wide travel garnered great trains of facts and observations, but an adequate theory to explain these came from the reading of Malthus's "Essay on Population." The book was certainly important, but its seed would have fallen on barren soil had not wide experience in dealing with natural phenomena already tilled it.

In his essay "Boy Life in a Country Town," G. Stanley Hall describes the educative situations in a Massachusetts town at about the middle of the nineteenth century. In the regular activities in home and community, the boy learned the rudiments of some sixty trades, and doubtless the girl learned quite as much in the duties of home-making. Children freely associated with other children throughout the neighborhood. They engaged in all the sports and games of the country side. Then, too, there were the husking bees, quilting parties, spelling schools, and many other types of social gatherings where the boy and the girl gained social insight. The value of the primary experiences in dealing with the whole processes of clothmaking—shearing the sheep, carding the wool, plying the loom—and fashioning the cloth into garments, or the making of tools, building homes and animal husbandry, is thus strikingly portrayed by Professor John Dewey:

> We can not overlook the factors of discipline and of character-building involved in this: Training in habits of order and industry, and in the idea of responsibility, of obligation to do something, to produce something, in the world. There was always something which needed to be done, and a real necessity that each member of the household should do his own part faithfully and in cooperation with others. Personalities which became effective

in action were bred and tested in the medium of action. Again, we can not overlook the importance for educational purposes of the close and intimate acquaintance got with nature at first hand, with real things and materials, with the actual processes of their manipulation, and the knowledge of their social necessities and uses. In all this there was continual training of observation, of ingenuity, constructive imagination, of logical thought and of the sense of reality acquired through first-hand contact with actualities. The educative forces of the domestic spinning and weaving, of the sawmill, the grist-mill, the cooper shop and the blacksmith forge, were continually operative.

No number of object-lessons, got up *as* object-lessons for the sake of giving information, can afford even the shadow of a substitute for acquaintance with the plants and animals of the farm and garden, acquired through actual living among them and caring for them. No training of sense organs in school, introduced for the sake of training, can begin to compete with the alertness and fulness of sense-life that comes through daily intimacy and interest in familiar occupations. Verbal memory can be trained in committing tasks, a certain discipline of the reasoning powers can be acquired through the lessons in science and mathematics; but, after all, this is somewhat remote and shadowy compared with the training of attention and of judgment that is acquired in having to do things with a real motive behind and a real outcome ahead.

Within a century our population has drifted from rural regions to urban centers so that now more than 50 per cent. of the people live in cities of 2,500 or more. With the development of machine processes of manufacture, many educative situations in home and community have gone to large manufacturing plants. Thus one by one these primary experiences have been taken away from the child. In lieu of these educative situations, school programs have been enlarged, new subjects have been added, and larger text-books have been adopted. Thus children, having lost by natural means their chances for actual work and play, fail to develop depth of emotions and breadth of knowledge about things, for they do not have opportunities to come into intimate contact with nature or to make things or to care for pets or to have responsibilities or tasks. Multitudes, flowing into cities built by a sturdy by-gone generation, are confused thereby for they can not understand the forces that are overpowering them. They are rushed from place to place, jerked down subways, and shot up elevators; they climb stairways by machinery, whisk lunch off of moving tables, and wonder if the North Star is still fixed.

Three quarters of a century ago, Herbert Spencer, the English philosopher, wrote that parents forced books upon children too early, for they did not recognize the superior importance of first-hand facts in experience to second-hand facts in books, and they failed to realize that book materials could be understood only through direct contact with things treated in these books. He wrote thus:

Possessed by a superstition which worships the symbols of knowledge instead of knowledge itself, they do not see that only when his acquaintance with the objects and processes of the household, the street and the fields, is becoming tolerably exhaustive, only then should a child be introduced to the new sources of information which books supply, and this, not only because immediate cognition is of far greater value than mediate cognition, but also because the words contained in books can rightly be interpreted into ideas only in proportion to the antecedent experience of things.

About a third of a century ago the eminent educator, Paul Hanus, criticized the isolation of the school from life and asserted that the methods of teaching the common branches were so bookish and abstract that children failed to make permanent mastery of their contents.

It was, therefore, quite generally true that the total permanent result of the first eight years of the pupil's school life was the ability to read, but not the reading habit; the ability to spell and write words, but no power of expression with the pen; a varying ability to add, subtract, multiply and divide simple numbers, integral and fractional, but much uncertainty in

all other arithmetical operations; a fragmentary book knowledge of names and places of our own country and of foreign countries; and some scrappy information relating to the history of the United States.

Since schools so frequently taught shreds of knowledge torn from their contexts, it is little wonder that pupils failed to comprehend these abstractions. Answers to examination questions, as the following, reveal such lack of intelligent mastery:

Wolfe declared he would rather repeat Gray's "Elegy" than take Quebec.

The Rosetta Stone was a missionary captured by the bandits.

The imperfect tense is used in French to express a future action in past time which does not take place at all.

Much butter is imported from Denmark because Danish cows have greater enterprise and superior technical education to ours.

It has happened that pupils living on the Mississippi River failed to identify it with the one studied in the geography. Quick, an English educator of the past century, asked a group of boys to locate Rome. Since none answered, he said, "It's geography." They immediately said, "In Italy." Some Boston school boys read "Wisconsin" on the badge of a traveler. When he asked where Wisconsin was, the boys were puzzled. The traveler exclaimed: "What? Haven't you studied geography?" They answered quickly, "You mean the Wisconsin in the geography; that's one of the forty-five states." A high-school graduate was surprised to discover that the Caesar of Latin and the Caesar of history and the Caesar of English literature were one and the same man.

As long as the home gave training in the manual skills and the community afforded educative situations in orienting youth, there was no great danger from the isolation of the school from active life, and the imperfect mastery of the materials taught. With the increasing complexity of social forces and the consequent lessening opportunities for participation in the fundamental community activities, the schools must compensate for these losses by affording means of vicariously participating in these activities. They must help the child to organize his world and to orient himself in it. "To see life clearly and see it whole" is an important function of the school. What Howard R. Driggs discovered in regard to cities should be the experience of every child in the larger world of things. He and his brother went to Chicago in 1893 to see the World's Fair. They were as much lost in the large city as were the "babes lost in the woods." By chance they met a friend who told them to go to the top of the Masonic Temple and look over the city.

As we walked around the observatory platform, the city in all its settings spread itself like an animated map before and below us. Out to the east, Lake Michigan; to the south, west and north, the checkered mass of business blocks and other buildings spreading far away over the Illinois prairie. The whole plan of the city was revealed in one bird's eye view. Since that sight I have never been at a loss to direct myself in Chicago. And since then, too, whenever I visit a large city for the first time, I always try to get to the top of some hill or skyscraper and take in the city as a whole.

Schools are attempting this orientation by introducing general courses in science, language, mathematics and literature. Educational guidance and vocational guidance are also helpful for this purpose.

The schools are also slowly changing their methods of teaching to secure this end. Problem-solving replaces the extreme emphasis on memory work in the older education; conduct is an end far more sought after than isolated information; principles are developed as problematic situations require their use; and school situations duplicate life situations as far as that can be accomplished. Field trips, pageants, dramatization, and other like devices make real many of the school materials of older days. A third of a century ago, Professor Dewey intro-

duced into the University of Chicago Elementary School a kind of approach which he called "Occupations." An abridged statement of his philosophy follows:

By occupation, I mean a mode of activity on the part of the child which reproduces, or runs parallel to, some form of work carried on in social life. The fundamental point in the psychology of an occupation is that it maintains a balance between the intellectual and the practical phases of experience. As an occupation it is active or motor; it finds expression through the physical organs, the eyes, hands, etc. But it also involves continual observation of materials, and continual planning and reflection, in order that the practical executive side may be successfully carried on. Now in the natural life of the individual there is always a reason for sense-observation. There is always some need, coming from an end to be reached, that makes one look about to discover and discriminate whatever will assist him. Normal sensations operate as clues, as aids, as stimuli, in directing activity in what has to be done; they are not ends in themselves. The same principle applies to normal thinking. It also does not occur for its own sake, nor end in itself. It arises from the need of meeting some difficulty, in reflecting upon the best way of overcoming it, and thus leads to planning, to projecting mentally the result to be reached, and deciding upon the steps necessary and the serial order. This concrete logic of action precedes the logic of pure speculation or abstract investigation; and through the mental habits that it forms it is the best preparation for the latter.

The several activities necessary for the securing of food, transportation of these necessary food supplies, weaving and cloth-making, tools and their uses and many other processes actually used in out-of-school life formed the basis of their study, not as trade information but as a means of understanding life activities. Following Professor Dewey's lead the reorganized schools of Russia devote much of the first four years of school life to the study of the village activities surrounding the child. The elements of mathematics, geography, civics and history are introduced as they help to interpret the social and economic life of the village. In "Schools of To-morrow," Dewey describes a number of schools that are attempting to introduce activities in order that, by means of participation, the child may see life clearly and as a whole. Although schools of private adventure and experimental schools in universities have taken the lead there are numerous public schools that are quietly pushing toward this goal. The Junior Republic at Freeville, New York, called "an experiment in democracy," has attempted to duplicate all the activities that an ordinary community pursues. The juvenile citizens work and receive their wages; they perform the duties of several civic offices, and, by means of this participation, they master the necessary skills, knowledges and emotional sets for good citizenship in their own republic. Perhaps the most spectacular of all the attempts to get experience first hand is the floating university. Students of botany and zoology have rare opportunities for study at the botanical gardens in Java and Ceylon, the aquariums at Honolulu and Naples, and the zoological gardens in Hamburg and London. Students of the social sciences have just as rare opportunities in studying the different races, their customs and traditions.

Life is full and vast in proportion to the fullness and vastness of the life of the persons experiencing it. So too, the book is significant in proportion to the significance of the experiences that the reader brings to interpret the ideas of the author. Hence, book learning and school work must be based on primary experiences, must interpret them and finally lead to a clear and whole view of life.

SCIENCE AND IMAGINATION

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THERE is little novelty in the statement that mathematics is the essence of science, and almost as little novelty in the statement that mathematics is an art. That mathematics plays the premier rôle in science is, in fact, an old notion, and one which has found frequent expression ever since the time of Pythagoras' famous and prophetic dictum that the nature of things lay in number. So common has it been for scientists and philosophers to comment on this dependence that the problem of adducing suitable quotations is distinctly one of selection, rather than search. Only two quotations will be given here, one from a preeminent scientist and one from a great philosopher. In Laplace's essay on probabilities occurs the statement, "All the effects of nature are but mathematical results of a small number of immutable laws"; while Kant has said, "I contend that each natural science is a real science only in so far as it is mathematics."

Not so ancient or so generally held is the notion that mathematics is an art. Even near the end of the twentieth century Boltzmann, describing some memoirs of Kirchoff, spoke of these mathematical essays as having uncommon beauty, and then felt it necessary to add, " 'Beauty?' I hear you ask: 'Do not the graces flee where integrals stretch forth their necks?' " Shortly after 1900, however, one of the great American mathematicians said, "I like to look at mathematics almost more as an art than as a science"; while from Bertrand Russell we have the statement, "Mathematics, rightly viewed, possesses supreme beauty—a beauty cold and austere, like that of sculpture."

Thus the statements, "Mathematics is the essence of science" and "Mathematics is an art," are by no means new statements. We would scarcely expect that any such simple, natural and general pronouncements would have escaped previous expression. Mathematicians have a professional reason for being particularly skeptical concerning the probable novelty of any such statement, for they may easily reckon that, if four words be chosen from the dictionary at random, the chance production of the sentence, "Mathematics is an art," is a million million million times more likely than is the dealing of any particular hand around the bridge table. The topic under consideration is, thus, an old one, but one which deserves continual reexamination as our attitude toward mathematics and science changes. And the time now seems particularly appropriate for such examination, since our views of the purposes and possibilities of scientific theories are in the process of so fundamental a change. The previous sentences have referred, in general, to "science," but further consideration will, for several reasons, be restricted to physics. This is not, it would seem, an essential restriction. The restriction exists partly because physics is the most completely developed science, and partly merely because the writer is not qualified to speak of other fields of science. Physics, however, deserves and can bear this special attention. It is surely a basic science; it is probably fair to pronounce it the basic science. John Dewey has recently expressed the dependence of all other sciences on physics by remarking, "Chemistry waited on the advance of physics; the sciences of living

things required the materials and methods of physics and chemistry in order to make headway. Human psychology ceased to be speculative opinion only when biological and physiological conclusions were available."

It is thus our purpose to consider the relationship between physics and mathematics, and that between mathematics and art; and, more particularly, it is our purpose, as the title suggests, to point out the rôle which imagination plays in the development of mathematics and physics. A double thesis will be defended. It will be argued that mathematics, as we view it to-day, is an artistic production of the creative imagination; and it will be argued that physics is to-day in the process of becoming almost purely mathematical in structure.

It has become quite fashionable, of late, to speak of the beauty of mathematics and to refer to mathematics as an art. It may seem somewhat ungracious to point it out, but such statements have frequently been made by persons who certainly do not know what mathematics is, and who very possibly do not know what art is. It is dangerously attractive for one to make such gestures, courteous though they be, towards that which one respects and admires, even though he neither appreciates nor understands. Grandly to say that mathematics is an art, carries with it a pleasant implication that the speaker, in the slanguage of to-day, "Knows his mathematics" and "Knows his art." Thus this statement has sometimes been one of those rebounding compliments whose real purpose is to reveal the erudition and culture of the maker. There is fairly close agreement among mathematicians as to the nature of their subject, but when we speak of art, we must proceed with caution and reserve, well aware that there are as many definitions of art as there are thinking men.

It will be necessary, in the first place, to remind ourselves of a few familiar facts concerning mathematics itself. The first great organization of mathematics occurred in Greece in the few centuries immediately preceding the birth of Christ. This organization is epitomized in the writings of Euclid. The Greek geometers recognized clearly the necessity that mathematics, as a logical structure, start somewhere, and they exhibited, at the outset of their arguments, the primitive concepts or elements which the argument was to concern and the primitive propositions or axioms concerning these elements. The primitive elements of their geometry were such things as "points," "lines," "planes," etc. These elements were, to them, entities which were so well known and so widely recognized as to need little description. They said, for example, that a "point" was that which had no dimensions, not because they thought that this remark uniquely and completely defined what they meant by points, but merely to indicate to the reader that by the word "point" the writer meant that familiar dimensionless object which the reader was himself accustomed to call a point. That is, the so-called "definitions" of the elements were relatively vague and informal remarks, whose real purpose was merely to identify the concepts in the writer's mind with concepts the reader was assumed already to possess. The "axioms" were, to them, self-evidently true statements about the familiar elements. That their statements concerning the elements were for the purpose of identification rather than of definition is clear from the fact that the axioms were supposed self-evidently true. A statement can not be viewed as self-evidently true unless it concerns familiar, rather than new concepts. Granting the familiar elements and certain self-evidently true relations between them, the Greek mathematician then carried out logical arguments which resulted in interesting further relations, called

theorems. The significant feature of this structure is the clear recognition of the necessity for an explicit and accepted basis of fact and concept, it being the task of the mathematician to discover all the relationships which are logical consequences of this basis.

It took mathematics roughly twenty centuries to materially improve on this conception. It is true that for centuries there had been vague misgivings concerning the axioms of Euclid. The famous seventh axiom concerning the number of lines that can be drawn through a point parallel to a given line, did not, even to men of that day, have quite the clear ring that a self-evident truth should have. Mathematicians, logicians, philosophers and theologians (this was back in those ripe days when party lines were not so strictly drawn) investigated this axiom, attempting to show that it was a logical consequence of the other more obvious axioms. These attempts consistently failed. Finally, in 1733, a geometer and logician named Saccheri attempted to show that any departure from this axiom would lead to inconsistencies. To his surprise, the inconsistencies did not develop. It is important to notice that, although this particular axiom was under close scrutiny, its truth was not suspect. It was still held that axioms should be self-evident truths; the only difficulty was that this particular axiom seemed unsatisfactory. The impetus for the real change in view-point came from the geometrical writings, published shortly after 1825, of Lobachefski and Bolyai. The old naïve belief that the postulates of Euclid were self-evident truths, or that the less evident ones were capable of proof on the basis of the more evident ones, was completely overthrown by the fact, established independently by these two geometers, that it was possible materially to alter these postulates and logically derive new bodies of doctrine, just as self-consistent and as inherently plausible as the old. The theories these two great geometers inaugurated are the so-called non-Euclidean geometries which have played so significant a rôle in the development of the theory of relativity. A second great impetus came from the work of Weierstrass, Méray, Dedekind, Cantor and later mathematicians concerning the relationship between analysis and the theory of the integers.

Without stopping to trace the steps by which the change in view-point has occurred, one can summarize the result in this way: A branch of modern mathematics, like Greek geometry, consists of the logically consistent consequences of an original set of propositions about an original set of elements. Our ideas, however, concerning these original propositions and elements have experienced great change. The original propositions we no longer call axioms and regard as self-evident; we call them postulates, and regard it to be without meaning to inquire concerning their truth. The original elements we no longer "define" or describe in the hope that the reader will recognize them. The elements of a modern theory are quite undefined, except in so far as one may view as a defining qualification the statement that the elements satisfy the postulates.

Thus modern mathematics differs essentially in structure from the mathematics which prevailed up to the nineteenth century. Granted the postulational basis, modern mathematics proceeds in much the same way as did the older discipline. The problems have become more involved and more subtle, so that the logical technique required is more extensive and delicate. The fact that the mathematician is perfectly free in his choice of postulation basis brings into mathematics some questions of a quite new nature. As regards our present argument, however, the important

point is that the new attitude towards the beginning of mathematics has brought with it an entirely new attitude towards the subject as a whole.

There are two chief aspects of this new attitude. The first results from the fact that the postulational (rather than axiomatic) character of modern mathematics entirely severs the previous supposed connection between mathematics and truth, and replaces this by the less pretentious but more definite quality of logical consistency. The Greeks naturally viewed their theorems as true, since they were the logical consequences of self-evident truths; but the postulates of a modern theory, far from being self-evident truths, are pure assumptions and have no concern with truth at all. Mathematics does not even understand the question "Is this statement true?" but concentrates her powers solely on attacking, with truly awful rigor, the question "Is this statement tautological?" To those not versed in mathematics this is a startling admission, for the "man in the street" has a profound and almost mystic respect for what he thinks of as the "truth" of mathematics. When the popular orator wishes to reach the pinnacle of finality, he thunders out that something is "mathematically true." He intends to thus convey, and usually does convey, the idea that it would be nothing short of indecent insanity to doubt his statement. But it is important to see that when the man in the street views mathematics as a subject austerely true, he ascribes to mathematics a virtue she not only does not claim, but the existence of which she does not even recognize.

A second particularly important feature of the new attitude towards mathematics is the great increase of significance which has resulted from the lack of definition of the elements. The theory is no longer merely a theory concerning particular things which behave in a certain way, but rather a general theory concerning all things which behave in this way. For example, since Weierstrass and Cantor have shown us that all analysis is reducible to statements about integers and since Peano has shown us that the theory of integers is a special instance of the general theory of any infinite sequence satisfying a few simple postulates, we now appreciate that any theorem of analysis can be interpreted in terms of such general sequences. To take a more striking example, the postulates at the base of the Dirac's abstract formulation of quantum theory are, with a minor change, those used in general theories of linear sets. Thus the theorems of this abstract branch of pure mathematics are (with suitable modification) theorems of quantum theory.

It is with all seriousness, then, that one of the leading authorities defines mathematics as the subject in which we never know what we are talking about, or whether what we are saying is true. Just preceding this famous definition, Mr. Bertrand Russell said:

> Pure mathematics consists entirely of such asseverations as that, if such and such a proposition is true of anything, then such and such another proposition is true of that same thing. It is essential not to discuss whether the first proposition is really true, and not to mention what the anything is of which it is supposed to be true. If our hypothesis is about anything, and not about some one or more particular things, then our deductions constitute mathematics.

Having gone thus far, it will be well, before proceeding with our main argument, to barely mention certain important considerations with which we will not be concerned. It would be unfortunate to leave the impression that the two aspects of newer mathematics just discussed are its only distinguishing features. The new attitude has brought new problems of great significance, and has been responsible for great advances

not hinted at above. For example, if one's original assumptions are self-evident truths, then they naturally are consistent; but if they are pure assumptions, one has an important task, namely, that of developing the logical mechanism for scrutinizing a set of assumptions relative to their reducibility and consistency. Furthermore, the new mathematics has developed a standard of rigor quite unprecedented. The influence of this new standard of rigor on thought in general, and even on logic itself, has been very great, but can not be discussed here. We are apt to think of the assistance mathematics has lent to astronomy, physics, the engineering sciences, etc., as being the greatest monument to her usefulness, but it may well be that the greatest debt that progress will eventually owe mathematics will be due her for the cleansing and purifying honesty she has insisted upon in all intellectual processes. One who was, so to speak, raised on undefined elements, is not likely to be deluded into a false sense of understanding when there is presented to him an argument which turns on a supposed understanding of concepts actually quite vague and undefined, but which, from mere long usage, we have regarded as familiar. One who was trained in the school of postulational method realizes keenly that an "explanation" in any intellectual field is the setting forth of the connection between two logical levels—a higher or more complex level, on which is the matter to be explained, and a lower or more simple level, on which are found the terms of the explanation. And since explanations are of this sort, it is clear that the sense and value of the explanation is vague if not altogether absent unless the lower as well as the higher level is specifically scrutinized.

Important as are the considerations just mentioned, they are not our principal concern here. We are now in a position to defend our first proposition, "Mathematics is an art," and we shall see that an appreciation of the spirit of modern mathematics is essential to the discussion. The point of central significance seems to be this: The purely assumptive character of modern postulational mathematics makes it clear that a mathematician is not a discoverer, but a creator. To be sure, not all that is created is art; but it would surely seem that no activity has a right to enter the contest for recognition as artistic activity until it can first establish itself as creative activity. The mathematician is not merely the industrious janitor of a dark and dirty room, grubbing about in the corners in the hope that he may finally uncover and dust off a preexisting truth. He is engaged in the far more exciting task of exercising his own creative imagination, and of creating complicated logical patterns of great beauty. In the early stages of photography, the operator was essentially a discoverer. He went about locating faces or objects or scenes which he caused his apparatus to duplicate with slavish accuracy. Photography became an art when the operator came to realize that he need not limit himself to the discovery and duplication of existing forms and scenes. He found that he could use soft focus lenses, and that he could so manipulate his developing and printing processes as to bring the whole result under his conscious and selective control. Quite similar has been the experience of the mathematician.

It is difficult to say what it is that decides whether or not a creation is a work of art. It seems to be largely a matter of the subjective reaction which the creation arouses; but it will be dangerously easy to argue in terms of subjective reactions. When a man reads a paper by Einstein, and then goes about beating his breast, tearing his hair and declaring that the paper is a great

work of art, we are not so likely to agree with him as we are to suspect that he is a bit balmy. If thousands of respectable citizens were to read the paper, and were universally struck by its artistic qualities, then we might be ready to accept the evidence of such a subjective reaction. But, unfortunately, mathematics is a very exclusive discipline, written in a condensed jargon which it takes years to master, and it can never hope to gain general direct appreciation. So we will do well to confine our argument almost entirely to objective qualities of mathematics, although this is an obviously severe limitation.

We may first consider certain similarities between the actual procedure of the mathematician and artistic workers in other fields. When the mathematician has finished one task and is looking about him for a new one, the situation that confronts him is very similar to that which would confront a painter or a poet under similar circumstances. Neither is a mere explorer or discoverer. Each is a potential creator. Each has before him a choice of media. He may choose the sonnet form, the language of geometry, the sculptor's chisel, the algebraic approach, the etcher's needle, the tensor method or what he will. His medium chosen, his subject is itself restricted only by the bounds of his imaginative faculty. He may choose a homely and familiar scene, as do the genre painters and as do some mathematicians. Or he may cut as loose from tradition as did Blake, Grassmann, Picasso and Einstein. In the development of his subject, each may owe to external nature as detailed a debt as he chooses. He may seek to imitate nature meticulously and microscopically, as did certain of the Dutch masters and as does the theoretical physicist of to-day. Or the mathematician may create logical patterns as purely unimaginative as the geometrical pattern of the designer of rugs or fabrics. He may even let his imagination run riot, as do the most bizarre of modern painters and poets, and as mathematicians have often done. Having chosen his medium, subject and style, the activity of the mathematician is subject to a sort of artistic restraint, as is the activity of a sculptor or poet. He experiences a limitation of means which seems to be a basic characteristic of any artistic process. The mathematician has to use (at least ordinarily) the canons of logic, just as the poet has to use (ordinarily) accepted language. Unless he is a truly great pioneer, the mathematician is limited by the traditions of his subject. Such limitations, however, are characteristic of the restraint of any decent art. One does not write a sonnet of twenty lines, nor does he carve a marble and then touch it up with oil paints.

The actual activity of the mathematician thus shows striking similarity to the activity of the composer, the poet or the painter. As regards the product of the mathematician, it is more difficult to say what it is that makes those judge it to be artistic who appreciate it at all. There are, however, certain qualities of a fine piece of mathematics which permit description in terms familiar to any one. For example, there is, to mention first a less important point, the evidence of mastery of technique. There is the artistic quality of condensation or concentration of significance. This is a familiar enough quality in all recognized art forms. The clearest illustration, perhaps, comes from poetry, where one beautiful line often contains as much as a whole prose essay. Similarly, mathematics, using as a containing vessel for the thought a powerful notation, distills off the lighter vapors of minor significance, and obtains a residue which is largely unencumbered by non-essentials. An inner simplicity is a characteristic of much art and of much good mathematics—not, to be sure, mere lazy sim-

plicity that results from considering only a simple situation, but the successful simplicity that is hardly won. Furthermore, great mathematics, like any great art, has an implication beyond the obvious. It grows on one in importance and significance as he ponders over it. Illustrations of this, in mathematics, are almost too well known to deserve mention. The non-Euclidean geometry and the absolute differential calculus of one generation is used in the relativity theory of the next. The theory of groups, long viewed as one of the most abstract theories of pure mathematics, now turns out to be fundamental in atomic theories. The quality, however, of mathematics which seems of greatest artistic significance is its universality. It has been noted above that one of the distinguishing features of modern mathematics is the lack of definition and consequent generality of the elements of the theory. There is, to be sure, art which refers to the particular; but that which adequately treats of the universal is, *ipso facto,* art.

Any one who has experienced the esthetic thrill which mathematics can induce realizes the inadequacy of these statements. He knows that mathematics not only has beauty, but that it is a pure beauty of relation and structure, condensed and unified in its expression, unsuspectedly rich in its implications and universal in its significance. He knows that the mathematician is that emancipated sculptor who deals in form freed of substance.

Thus there is good reason to believe that mathematics is an art, and that the creative imagination plays a dominant rôle in the development of that art. It remains to see the extent to which physics has become mathematical. In the first place, physics is a preeminently quantitative science, having concern only for that which is measurable. It is thus evident at once that mathematics is germane to all the legitimate considerations of any physical theory. The aim of physics is to "explain" the measurements which result from experiment. The theoretical physics which explains the experimental result is nothing more or less than a body of mathematical doctrine to which is added, as an essential part, a physical interpretation of the abstract terms of the theory, this interpretation arising from an identification of certain concepts of the theory with certain measurable physical entities. When once a physicist has identified concepts of a pure mathematical theory with certain physical entities, he then has a right to ask, "Is this mathematico-physical theory true or is it not?" That is, do the actual measurements of the physical entities satisfy the relations of the theory? A physicist, therefore, is precisely a man who, by particularizing and materializing the elements of a mathematical theory, earns the right to ask that previously forbidden question, "Is it true?"

The rôle which mathematics has played in physics has been, in considerable measure, governed by the views that have been held, at various times, concerning the subtle process by means of which a theory explains the phenomena it concerns. Physical theories seem to explain facts in two chief ways, by analogy and by simplification. To illustrate these two types of explanation, consider the familiar example of the kinetic theory of gases. A gas, it is found, exerts a pressure on the walls of a containing vessel which is the same as would be the average force of bombardment due to a vast horde of tiny, perfectly elastic spheres buffeting their ways about in the vessel. This furnishes a mental picture to have before us, and when we further discover that many of the macroscopic properties of the gas are "explainable" on the basis of applying the familiar laws of dynam-

ics to these numerous elastic spheres, we feel that this is a satisfying theory which does indeed "explain" the facts. To most physicists this theory probably explains partly by analogy and partly by simplification. To the extent to which one believes that he now understands the pressure due to a gas because he previously understood the mechanics of perfectly elastic collision, to this extent the theory explains by analogy. To the extent, however, that one feels the real value of this theory to be the correlating of surprisingly diverse phenomena on the basis of comparatively meager assumption, to that extent the theory explains by simplification. To consider one more example, electrodynamical theory as formulated in the Maxwell field equations was probably viewed by Maxwell himself to explain largely by analogy, since he laid great store by the mechanical models which aided him in developing the theory. At the present time, however, we judge this theory to explain almost solely by simplification. There is neither time nor need to argue here that explanations by analogy are losing popularity, and that there is a fast-growing tendency to regard with actual distrust the suggestions that come from the use of models. The mathematician will realize at once that explanation by analogy bears a close relation to the structure of Greek mathematics, in that it expresses new and complex facts in terms of the familiar and the supposedly self-evident. It is clear that such explanations are but postponements of that evil day of reckoning when some skeptic will question further. One of the most unfortunate aspects of the model theories of physics, moreover, arises from the chronological fact that the old and hence familiar concepts of physics, in particular, the concepts of mechanics, are not, from our present point of view, fundamental concepts. One finds those who still attempt to explain the basic science of electrodynamics in terms of those mechanical concepts which, although they are old and falsely familiar, should, in fact, emerge from electrodynamical theory. Explanation by simplification, on the other hand, is quite in the spirit of modern mathematics. It is not ultimate explanation, to be sure, but we realise that to be as impossible as ultimate proof.

Physics, then, is but applied mathematics. It differs enormously from mathematics as regards the actual activity of its followers, but it differs from mathematics, in logical structure, in only two regards. Certain elements of the theory are identified with measurable entities, and the theory thus becomes one which may, on the test of experiment, prove to be false or true. There are two ways in which one can test the truth of a physical theory. One can subject its end conclusions to experimental verification; or one may test whether or not physical entities exist which actually satisfy the relations assumed as postulates in the mathematical theory. If the latter test can be made and if it succeed, then the whole mathematical theory obviously becomes, at one stroke, a true physical theory. If only the more remote theorems of the theory can be tested experimentally, then the situation is less definite. One can not, in general, then claim that the postulates are necessarily "true" in a physical sense. In fact, the situation may be even more vague than this. The identification with measurable entities may not refer to all or any of the primitive elements of the theory, but rather to constructs occurring in the development of the theory, formed from these primitive elements. The end theorems of the theory may then be true without our being able to give any physical interpretation whatsoever to the primitive elements themselves. This seems to be

the actual structure of important modern physical theories. One can appreciate the new tendency if he compares the atomic theories of ten or fifteen years ago with present atomic theories. The familiar theory developed largely by Rutherford and Bohr described the motions and interactions of a nucleus sun and various planetary electrons. One had a definite picture of an atom, and believed that his model exhibited so satisfactory and detailed a correlation with experiment that one was justified in concluding that atoms were actually constructed after the pattern of the model. The modern quantum theory of the atom, however, is quite a different sort of affair. It starts, as formulated by Dirac, with abstract variables called "states" and "observables" which satisfy certain assumed postulates. An algebra of these variables is then developed, and, near the end of the work, a decoding process is introduced so that equations in these abstract variables may be formally translated into statements concerning the result of certain experimental measurements. To ask, in this theory, what the inside of an atom looks like or to ask concerning the path of an electron inside an atom are meaningless and silly questions. One has simply constructed a formal mathematical theory, which, at some stage in its development, is decoded into physical language and is thus made susceptible of experimental test. The important matter, from our present point of view, is that this decoding does not take place at the beginning of the theory. It is thus not possible to test directly whether or not the postulates are experimentally satisfied; nor is it possible to give physical meaning to the abstract variables with which the theory began.

If one is, then, to construct a physical theory by constructing a mathematical theory and adding to it a decoding or interpretative appendix, and if this physical interpretation is to occur so far along in the theory that one can not ask, "Are the postulates physically true?" nor can he even ask, "What is the physical interpretation of the terms in which the postulates are phrased?"—if this be the plan of a modern physical theory, then where, one may ask, is one to get the postulates with which one has to begin? In the earlier stages of physics one felt himself guided, in the choice of his original assumptions, by his previous experience in the laboratory and by his so-called physical intuition, just as the early mathematicians felt themselves guided by their judgments of the self-evident. The modern physicist has no such hold on so-called reality. He has grown to feel that nature is a very shy nymph who conceals from us mortals her personal charms, only allowing us the privilege of describing some of her more remote manifestations. Mr. J. W. N. Sullivan, in his charming essay called "Gallio, or The Tyranny of Science," says: "All that depends on the *structure* of reality belongs to physics, including other universes than ours. All that depends upon the *substance* of reality forever lies outside physics."

The upshot of the matter, then, is that modern physicists live in a world of their own making: and in the making of it they have been so little guided by the past that, almost as completely as is the case with pure mathematicians, it has been their creative imaginative faculties which have been most called into play. Modern science, like modern mathematics, is no materialistic Juggernaut; it is a creative and imaginative art.

If one is himself convinced that mathematics and physics are imaginative arts, he may finally wish to ask whether or not they have been so recognized by other artists. The answer comes, in beautiful form, from a sonnet of Edna St. Vincent Millay. She is speaking of geometry, a subject which,

fifty years ago, we would unhesitatingly have called mathematics, but which we now recognize to be mathematics only providing one is talking about so-called points, lines, planes, etc., but which we recognize to be physics if one is talking about points made by pencils, lines drawn on paper, etc. Indeed, we not only recognize geometry to be physics, but we have learned from Einstein that it is one of the most significant branches of physics. It is satisfying, then, to have the answer of the poetess refer to a subject which so admirably illustrates the arguments made above, and to have her poem, in its every detail, so completely in accord with the modern philosophy of mathematics and science:

Euclid alone has looked on Beauty bare.
Let all who prate of Beauty hold their peace,
And lay them prone upon the earth and cease
To ponder on themselves, the while they stare
At nothing, intricately drawn nowhere
In shapes of shifting lineage; let geese
Gabble and hiss, but heroes seek release
From dusty bondage into luminous air.

O blinding hour, O holy, terrible day,
When first the shaft into his vision shone
Of light anatomized! Euclid alone
Has looked on Beauty bare. Fortunate they
Who, though once only and then but far away,
Have heard her massive sandal set on stone.

HOW THE LAUGHING GULL, THE FEATHERED BUCCANEER OF FLORIDA WATERS, GETS ITS DINNER

By Dr. E. W. GUDGER

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SWINGING southwest and west from the tip of the mainland of the Florida peninsula at Jewfish Creek, the great submarine Florida plateau, with its bird-populated keys and its fish-inhabited reefs, ends abruptly in the archipelago of the Tortugas. In the 107 miles of this distance from Jewfish Station on Key Largo to Key West, the keys are so close together and the intervening water so shallow that the Florida East Coast Railroad has built an extension over and between them to that city. But in the seventy miles from Key West to Loggerhead Key, the breaks are too wide and the water too deep for man to bridge. And on these outer keys the little-disturbed wild life remains almost as it was sixty years ago.

The Tortugas (Islands of the Turtles) consist of seven small, treeless islets, composed of coral rock and sand heaped up by waves and winds, which with their surrounding reefs enclose a lagoon of forty or fifty square miles area, shallow for the most part but with intersecting channels of deep water. They are the last far-flung remnant of the Florida Keys, the Ultima Thule, the "jumping-off place," the land's end of the Florida Reef, and beyond is nothing but "blue water" until one reaches the Mexican coast one thousand miles away.

Here in this absolutely isolated spot it was my good fortune to spend four summers at the Marine Biological Laboratory of the Carnegie Institution of Washington studying fishes. The laboratory is located on Loggerhead Key, so called because the loggerhead turtles used formerly to "haul out" there in great numbers to lay their eggs in the sand. Two miles east of Loggerhead is Garden Key, covered over with the ruins of an old brick-built stronghold, Fort Jefferson, so named for Jefferson Davis, under whom as secretary of war it was begun in 1847. South of Garden Key is Bird Key, a bird sanctuary with a guardian warden during the breeding season when it is literally covered with birds, their eggs and young.

Sea birds abound here and may be seen perched on every available resting place, on buoys, channel stakes, old wrecks—everywhere that they can secure a footing. But although these are the "Turtle Islands" (they were named Tortugas in 1521) I have never witnessed the interesting sight which Zane Grey tells us in one of his books that he saw in the Bay of Tehuantepec. He says that "About noon, when the sun was hottest, we began to see birds standing on the backs of turtles [sleeping at the surface of the water]. . . . Terns and gulls and one booby made of these oval green backs a resting place." However, I can go Dr. William Beebe one better, although he saw in his Islands of the Tortoises (the Galapagos) "a noddy tern alight on the head of a pelican, without eliciting any protest."

Florida, including the Tortugas, belonged to Spain until it was finally ceded to the United States in 1821. Up to that time and even later piracy was rife and buccaneering very much the fashion in Gulf-Caribbean waters. The Tortugas, commanding the straits of

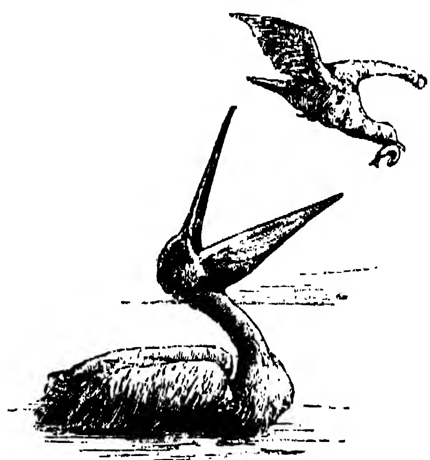
—*After Holder, 1892*

FIG. 1. THE LAUGHING GULL HAVING ALIGHTED ON THE HEAD OF THE PELICAN AWAITS HIS CHANCE TO STEAL THE FISH FROM THE LATTER'S BEAK.

Florida, the entrance to or if you so please the exit from the Gulf of Mexico, was an admirable location for a lair of the buccaneers. Moreover, having three deep water channels penetrating the lagoon, it could not be successfully blockaded. Hence for a long time it was a most desirable rendezvous for the pirates of the Gulf. And later still it was headquarters for the wreckers who plied their nefarious trade along the western keys. And about the same time it was a transshipping point for Mexican and Central American gun-runners, as J. Fenimore Cooper has written in his novel "Jack Tier." Now although buccaneers of the genus *Homo* have long since departed, those of the genus *Larus* still abound, and ply *their* nefarious trade brazenly and unchecked—as will now be shown.

In front of the sally-port of deserted Fort Jefferson on Garden Key, and separated from it by a deep channel, is Long Key, composed of white coral sand. This extends northeast and curves east to where a shallow channel nearly dry at low tide separates it from Bush Key, now composed only of dead coral heaped up by the waves, which in turn swings southeast and south. On these keys lived and nested many laughing or black-headed gulls (*Larus atricilla*), and in the shallow lagoon partly enclosed by these keys, some brown pelicans (*Pelecanus fuscus*) generally could be seen floating idly on the surface with their bills resting on their breasts, their eyes closed and their long necks curved until their heads rested on their backs, or sedately pursuing their prosaic task of catching fish.

Here one day toward the close of the season of 1914, while watching the sharks in the lagoon, I saw a laughing gull light squarely and securely on the head of a somnolent pelican. The pelican, thus rudely awakened, automatically arose in lumbering flight, the gull hovering closely around him, but seeing beneath him a fish swimming near the surface he dove down and seized it with his hooked bill. Floating on the surface, the pelican lifted his head and stretched out its neck and bill to get the fish in



—*After Holder, 1902*

FIG. 2. WHEN THE PELICAN LIFTS HIS BEAK AND STRAIGHTENS HIS NECK TO SWALLOW THE FISH, THE GULL ADROITLY SEIZES THE PREY AND FLIES AWAY WITH DERISIVE HA HA'S.

—*Slightly modified from Ealand, 1921*

Fig. 3. Laughing gulls teasing a brown pelican and alighting on its head to rob it of the little fishes with which its pouch is filled. Figure drawn to illustrate the scene in Key West Harbor seen by Audubon in 1832.

position to swallow head first—to prevent any casualties from its spiny fins catching in his throat—when the saucy gull again alighted on his head, reached around, deftly seized the fish and flew away with it amid a chorus of derisive ha-ha's from its fellows. This interesting thing happened several times that afternoon while I, immensely pleased, thought that I had witnessed a thing in bird behavior absolutely unknown to scientific men. But sad to say, I had no camera to secure a record of it, and unfortunately I never saw it again in the short time before leaving Tortugas.

But alas! "There is no new thing under the sun," as Ecclesiastes the Preacher well says. For, a few weeks later, when on my way north, I visited friends at Cocoanut Grove, Florida (near Miami), who lent me a copy of Dr. Charles F. Holder's charming book "Along the Florida Reef."[1] From 1859 to 1869 Holder's father, Dr. J. B. Holder (later a curator in the American Museum), resided at Fort Jefferson, while engaged in the study of the growth of corals. For nearly two years he also served as surgeon to the troops there. Charles F. Holder spent most of these ten years here, and accumulated a vast lore of sea things which he later put into many interesting books. Among other things, he witnessed an identical performance by the birds in this identical lagoon.

Holder first described this interesting incident in one of a series of delightful papers bearing the general title "Among the Florida Keys" in *St. Nicholas Magazine* for 1889.[2] These articles were later expanded into the book above named, and from it will now be set forth his own vivid account of what he saw illustrated by copies of his own pictures:

The old birds [pelicans] were hard at work, diving for fish in the lagoon. The boys watched one, which was near them, with no little curiosity. It would flutter an instant over its prey, then plunge down and with open, dip-net bill resting on the water, would adjust the catch in its capacious pouch beneath. In one of these expeditions a gull, with trained and eager eye, hovering near, settled down upon the pelican's broad head, and as the fish was tossed about, preparatory to swallowing it, the thievish gull adroitly snapped it up and sailed away with a derisive "Ha, ha!" while the pelican, as if accustomed to this sort of pocket-picking, flapped heavily up again to renew its search for food.

Years later I learned that Holder in his turn was not the first to see this interesting method by which the laughing gull procures its dinner. That great naturalist, John James Audubon, saw the same thing in 1832 and describes it in his "Birds of America." In his account of the brown pelican,[3] Audubon says of it that "it acts unwittingly as a sort of purveyor to the Gulls," and that when it has caught a number of small fishes and is endeavoring to swallow them "the Gull at that instant alights on the bill of the Pelican, or on its head, and seizes the fry" which the pelican thinks he has safely imprisoned for his dinner. In his account of the laughing gull[4] he relates that on May 10, 1832, the revenue cutter *Marion* furled her sails in the harbor at Key West and that "the Gulls laughed whilst our anchors were swiftly descending towards the marvelous productions of the deep." He then goes on:

They [the laughing gulls] were all busily engaged on wing, hovering here and there around the Brown Pelicans, intent on watching their plunges into the water, and all clamorously teasing their best benefactors. As with broadly extended pouch and lower mandible, the Pelican went down headlong, so gracefully followed the gay rosy-breasted Gull, which, on the brown bird's emerging, alighted nimbly on its very head, and with a gentle stoop instantly snatched

[1] New York, 1892.

[2] On page 781, Vol. 16, are this account and figures.

[3] "Birds of America," Vol. 7: 35. New York and Philadelphia, 1844.

[4] P. 141.

from the mouth of its purveyor the glittering fry that moment entrapped! . . . The sight of these manoeuvres rendered me almost frantic with delight. At times several Gulls would attempt to alight on the head of the same Pelican, but finding this impossible, they would at once sustain themselves around it, and snatch every morsel that escaped from the pouch of the great bird. So very dexterous were some of the Gulls at this sport, that I have actually seen them catch a little fish as it leaped from the yet partially open bill of the Pelican.

The accompanying figure, which very accurately portrays the scene, is copied from E. A. Ealand's "Animal Ingenuity of To-day,"[5] in which book he quotes the incident without adding anything to it. On looking at the figure and visualizing the scene, one can readily understand that Audubon was "frantic with delight" when he first saw this charming performance. That was certainly my feeling that day in June, 1914, when I in my turn saw "How the Laughing Gull Gets its Dinner."

[5] London, 1921.

THE USEFULNESS OF THE USELESS

By Dr. CHAS. N. GOULD

DIRECTOR, OKLAHOMA GEOLOGICAL SURVEY

Last week I found among the routine correspondence on my desk a letter from a friend inquiring if I knew of a young man whom he might employ as an assistant. This friend is the geologist for a small oil company operating in Oklahoma, and is engaged in general scouting for new oil fields. Among his other duties, he watches the various oil wells that are being drilled by his own company as well as by other companies in the region in which his company operates.

One sentence in his letter of inquiry struck me very forcibly. The young man whom he wished to employ must be able to identify microfossils, and must also be able to make heavy-mineral determinations—this in addition to general training in structural and stratigraphical geology and in the use of the plane table and telescopic alidade. He should also be versed in subsurface methods of correlation and know something of geophysical instruments.

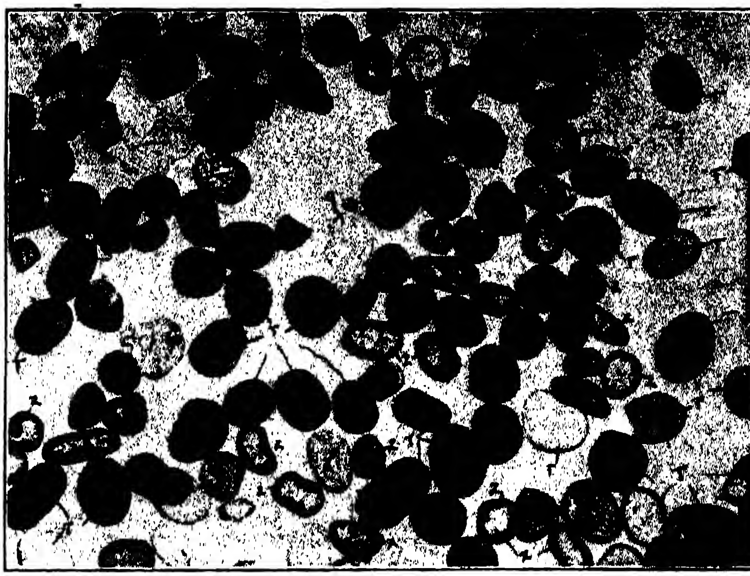
Pity the Poor Student

When one comes to think of it this is a rather large order for a young chap just out of college. But it is not an unusual demand. The young geologist who to-day graduates from any one of a score of schools of geology or petroleum engineering in the United States is supposed to have at his fingers' ends these various requirements. He must have sufficient training in engineering to use the alidade and plane table, and must be well enough acquainted with physics and higher mathematics to have at least an elementary knowledge of the magnetometer, torsion balance, seismograph and other geophysical instruments. He must know not only megascopic fossils, but microscopic forms as well, and this knowledge naturally presupposes some knowledge of zoology. He must understand the principles of stratigraphy and sedimentation, and have fairly good training in mineralogy and in igneous petrography.

The Place of Igneous Petrography

Ten years ago who would have thought that these somewhat diverse and more or less abstruse sciences would to-day have a practical application in this work-a-day world? Who could have imagined that such things as igneous petrography or the identification of sand grains under the microscope would be of commercial importance in one of the great industries of the world? Who could have had the temerity to suspect that the identification of tiny fossils under the microscope in the laboratory of the geologist would determine the matter of the expenditure of tens of thousands or hundreds of thousands of dollars in the drilling of deep wells in the search for oil? Yet these things are to-day part of the ordinary routine of many oil companies.

Ten years ago the men in the United States who were trained in petrography were rather few. The subject was supposed to have no particular commercial importance, and for that reason relatively few men concerned themselves with it. It was then one of the so-called "cultural" studies, something like Greek or psychology or higher mathematics. Students who came to school and followed the ordinary custom of browsing around among the different departments sometimes happened to drop into geol-



—*Oklahoma Geological Survey*

HEAVY MINERALS IN SIMPSON SANDSTONE, WILCOX SAND

FROM THE ARBUCKLE MOUNTAINS, CONTAINING ABOUT 75 PER CENT. TOURMALINE AND 25 PER CENT. ZIRCON. THE CRYSTALS ARE LABELED T AND Z RESPECTIVELY.

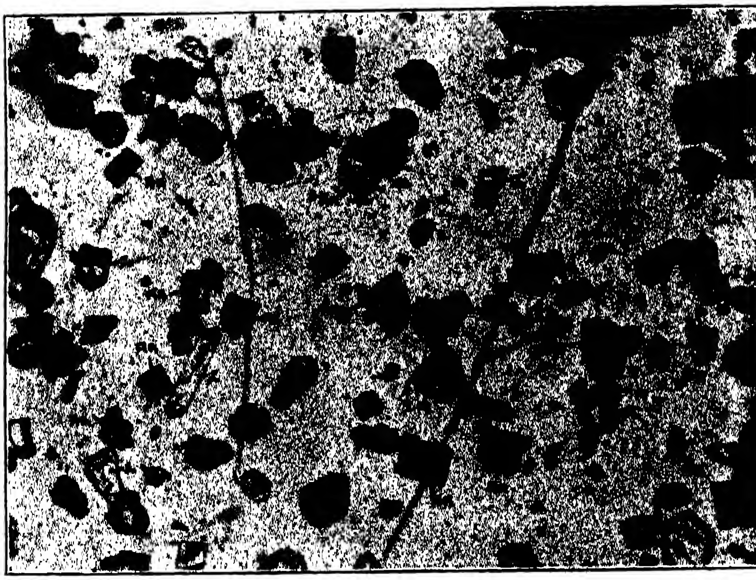
ogy, and in the natural course of events took mineralogy, and later, with no particular reason for so doing, wandered into classes in petrography. Very few of them, relatively speaking, really became interested in the subject, but the great majority took it just as they took all other subjects, because it was scheduled in the catalog and would produce credit which counted toward graduation and a diploma. Something like the medicine which the old-time doctor used to give, which was labeled, "Good for what ails you. Shake well before using."

But the possibility of putting to any practical use the information gained by studying sand grains and rocks under the microscope was far from the thoughts of those who studied these subjects. A few really enjoyed the science and became teachers in colleges, and so passed the science on, inflicting it on other students. A few practical men engaged in mining engineering or kindred professions occasionally used the subject. Some of these men, both engineers and college professors, wrote for technical journals and magazines. But no one would for a moment have classified the subject of igneous petrography among the popular, or so-called useful, sciences. It was not a "bread-and-butter" subject.

But all this has been changed, and almost over night. There is to-day a very urgent need for more students trained in petrography. And this need has burst upon us very suddenly. It was only a few years ago that the men connected with the scientific departments of the larger oil companies began to use heavy-mineral determinations in the correlation of deep well logs. These men found that certain beds of sandstone, especially those that were oil-producing under favorable structural conditions, possessed a rather definite mineral content.

HOW TO DETERMINE AN OIL SAND

If the drill in pounding its way downward encountered at a depth of 5,000 or



—*Oklahoma Geological Survey*

HEAVY MINERALS IN SIMPSON SANDSTONE, WILCOX SAND
FROM THE ARBUCKLE MOUNTAINS, CONTAINING ABOUT 85 PER CENT. ZIRCON AND 10 PER CENT. ANATASE AND SMALL AMOUNTS OF OTHER MINERALS.

6,000 feet a certain ledge of sandstone which did not contain oil, it was often of extreme importance to be able to tell whether or not this particular sandstone was the same as the one which, in another well of similar depth a few miles away, contained large amounts of oil. If this was the same ledge as the one which contained oil in the producing well, it would probably be useless to spend more money to drill deeper. If, however, the sands were not the same, and if the one just encountered lay at a higher level than the producing horizon, it would be the part of wisdom to drill deeper. The well had already cost a large amount of money, perhaps $75,000, possibly $100,000. It then became a very vital problem to determine by any known method whether or not the sand at the bottom of the hole was the one which in other areas produced oil, or whether it was some other sand.

Heavy-Mineral Determination

The chief way, and in many cases the only way yet discovered, in which this matter can be determined is by the microscopic examination of the sand grains. Experience has shown that certain sandstones contain rather definite proportions of certain minerals. Some of these minerals are easy to detect, others are not. The so-called heavy minerals, such as tourmaline, zircon, rutile, and the minerals composed of iron such as magnetite, hematite and pyrite, are usually easy to distinguish, and it is these that often form the basis for comparison and determination. It is no unusual occurrence, after a certain ledge of sandstone has been encountered, for drilling operations to stop, machinery to stand idle and workmen to loaf on the job while a sand sample from the bottom of a 5,000-foot well is sent hundreds of miles to the laboratory where the petrographer makes his tests. The question as to whether or not another $10,000 or $20,000 shall be spent in the deep hole, in addition to the $75,000 or $100,000 already expended, frequently rests upon the determination of the

particular type of sand grains under the microscope.

The Geologist's Clock

And so with the studies of microfossils. Fossils are the geologist's clock, the method by which he determines geologic time. Studies by many men in many lands for the last hundred years have shown that no two formations contain identically the same fossils. In the older stratified rocks, those of early Paleozoic age, certain rather primitive forms occur. As one comes higher and higher in the geologic section, the type of fossils changes, and there is shown a gradual, slow, but very determinable development of fossil forms from the older to the younger rocks.

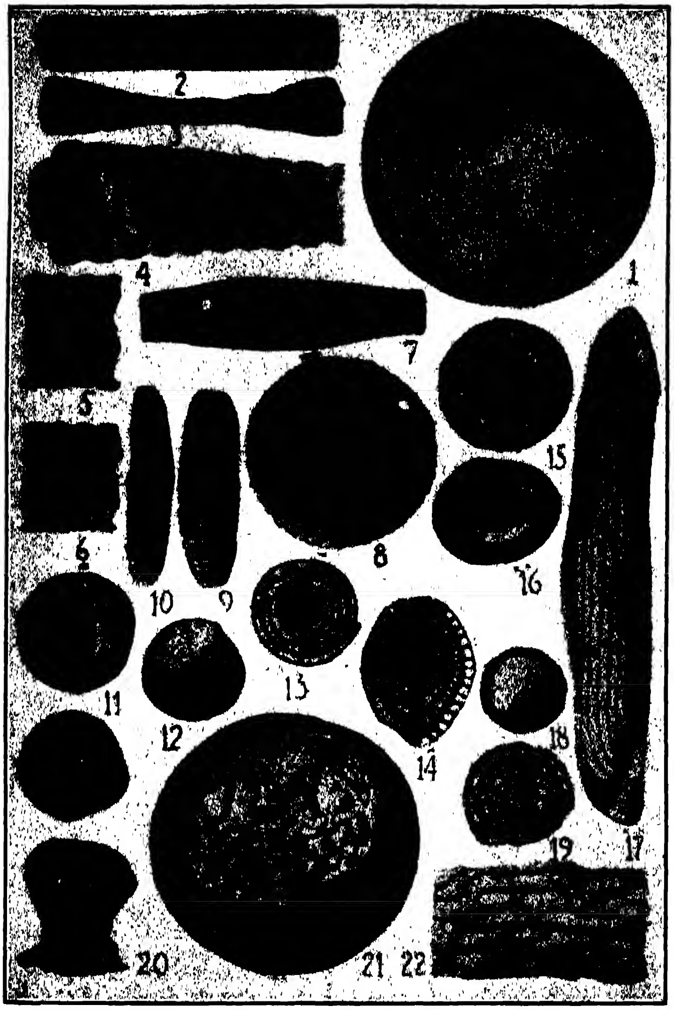
This story is told of James Hall, the veteran state geologist of New York many years ago. Dr. Hall stated that he was willing for any one to blindfold him, take him to any part of the state, turn him loose and permit him to find a fossil, claiming to be able to tell, if not the exact county, at least the general part of the state in which he was located. So with the trained paleontologist of to-day. You may throw into a tray fifty fossils selected at random from different geological horizons and from all parts of the world, and this paleontologist will be able to pick out the particular fossils from the various geological ages. True he probably will not be able to tell whether a certain Ordovician fossil came from Wales, from New York or from Missouri, or whether a certain Pennsylvanian fossil came from the coal fields of England, the coal fields of Pennsylvania or the coal fields of Oklahoma, but he can tell without question that the one fossil is Ordovician and the other Pennsylvanian.

Geologists have found this underlying principle of much value in identifying formations. The drill in penetrating downward passes through various ledges of rock, sometimes shale, sometimes limestone, sometimes sandstone. Many of these ledges, particularly the limestones and shales, contain large numbers of fossils. The fossils from the ledge at the bottom of the well will never be quite the same as those found in formations at the top of the well. This is especially true when the well passes through rocks of several different geological ages. So the oil man has found that the geologist by identifying these fossils is often able to determine the geological formation in which the drill is working, and, as in the case of heavy minerals, he will often be able to tell whether or not it is worth while to penetrate deeper in searching for a particular oil sand.

Microfossils

The difficulty is that the drill in pounding its way downward breaks up, mashes and destroys most of the larger fossils. Such forms as trilobites, corals, shells and most other fossils large enough to be seen with the naked eye are often so broken and macerated that their fragments can not be determined. Occasionally a recognizable fragment will come out of a drill hole, and very rarely an almost complete fossil may be obtained which will give the geologist a clue, but as a general rule the larger or megascopic fossils are so broken as to be unreliable as a means of determination.

This fact has given a great impetus to the science of micropaleontology. It has been found that most shales and many limestones contain great numbers of very minute fossil forms, those that are often too small to be seen with the naked eye. At the same time, it has been discovered that these microforms are diagnostic, that is to say, they are valuable for the determination of different strata. These little fellows are the forms that are now being used by the paleontologist in determining the identity of deep-lying formations.



SOME MICROSCOPIC FOSSILS

THE PHOTOGRAPHS SHOW SEVERAL TYPES OF MINUTE FORMS OF LIFE, THE ILLUSTRATIONS BEING GREATLY ENLARGED. (THE TWO ILLUSTRATIONS ARE FROM "FORAMINIFERA, THEIR CLASSIFICATION AND ECONOMIC USE," BY JOSEPH A. CUSHMANN.)

Shales and fragments of limestones from the bottom of the well are sent to the laboratory, and this material is washed, sieved, dried and studied under the high-powered microscope, and the results obtained are used to determine the particular geological formation in which the drill is working. As in the case of heavy minerals, it often happens that operations at the well will be suspended for several days while the cuttings from the bottom of the hole are sent to the laboratory to give the micropaleontologist an opportunity to pass upon them.

Ten years ago there were perhaps not more than a half dozen men in the United States who gave any particular attention to micropaleontology. As in the case of igneous petrography, the subject had no commercial appeal. "There was no eating in it." The few

SOME MICROSCOPIC FOSSILS

men who studied microfossils were generally considered pedants or mild sorts of cranks, whose labors served no useful purpose. They were devotees of "pure" science, using the term "pure" to mean something which had no particular utilitarian purpose.

What Does the Oil Man Want?

To-day the condition is very different. When the oil man once found that the paleontologist by a study of these minute forms could actually aid him in "putting oil into the tank" he at once became an advocate of micropaleontology.

Not that the oil man knows what it is all about. Far otherwise. The ordinary petroleum executive has no love for science as such, and has no burning desire to promote scientific research. What he wants is to strike a gusher formation and get the oil out of the ground and into his own tanks before the other fellow has a chance at it. But he has learned that the micropaleontologist as well as the petrographer in his

determinations of heavy minerals has something which will often help him to put oil into the tank. Therefore, for that reason and for no other, he is strong for scientific work, which he by no means understands, as long as it can help find the oil.

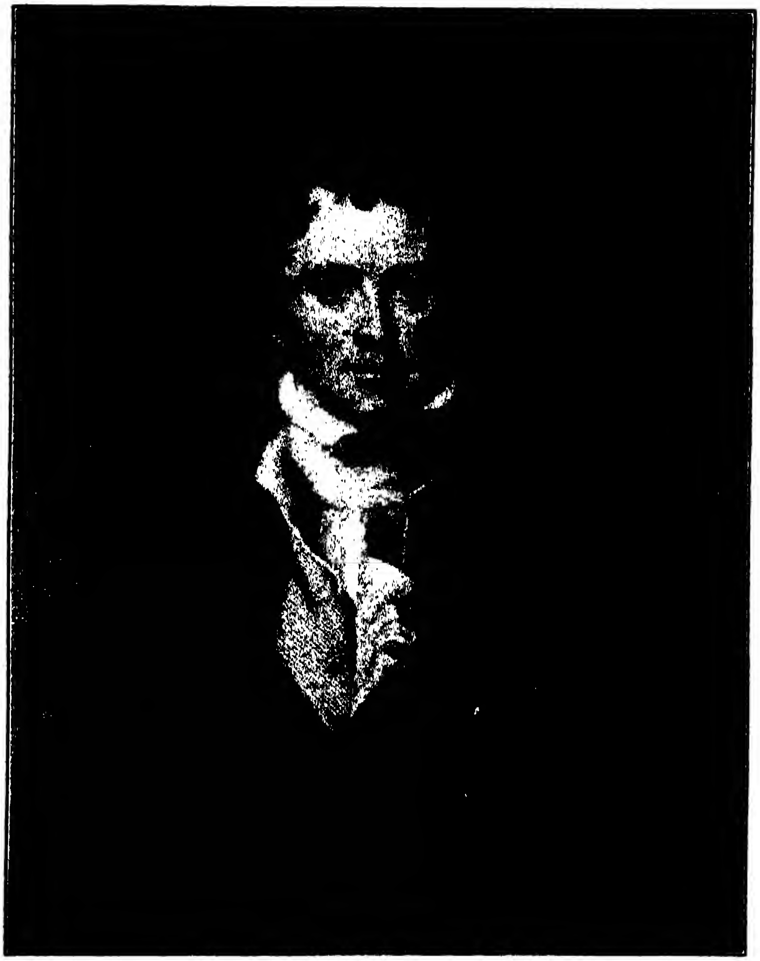
"Pure" Science on the Boom

All of this means that these two sciences, petrography and micropaleontology, are now "on the boom," in many universities. Young men and women have learned where these subjects are well taught and to-day the men who teach them well are overwhelmed with students. In some of our American universities the departments of geology and paleontology are to-day overcrowded, and, on account of inadequate teaching personnel and insufficient laboratory facilities, are turning away students who desire to enter.

In the case of micropaleontology, until within the last few months there never has been a suitable text-book on the subject, and to-day the science is in an unformed state because the various workers have not yet been able to record in type and in figures the many new forms that are being discovered. A new publication, the *Journal of Paleontology,* and various paleontological reports published by geological surveys and magazines are now busy recording the many new genera and species that are being discovered by the workers in this field. During the next decade the science should have opportunity to crystallize, and the nomenclature to become fairly well established.

Making Useful the Useless

One might unduly enlarge this article to include other of the various new methods being used to discover supplies of petroleum, but these two examples of petrography and micropaleontology must suffice. The use of the telescopic alidade and plane table for making contour maps might well be discussed. Or something might be added regarding the training of young men in the use of geophysical methods or the work now going forward in various states for working out geothermal gradients by taking deep-well temperatures. The ceramics method of burning clays and observing their colloidal qualities and the analyses of subsurface brines might be described. All these methods and others not known a decade ago are now being used in the petroleum industry. Other methods are only to-day peeping over the horizon. Just how far they will be found to be practical no one knows. However, those of us who have watched the development of the industry for a quarter of a century believe that as the years come and go these and other new methods will continue to be developed and improvements made in the search for and recovery of oil, and that many things now considered useless by the man on the street will be found to be useful.



SIR HUMPHRY DAVY

By Professor BENJAMIN HARROW

COLLEGE OF THE CITY OF NEW YORK

THE centenary of the death of Sir Humphry Davy has recently been observed. At this time it might not be amiss to recount some of the activities of one of England's greatest chemists.

Davy's fame rests upon a number of outstanding contributions: the physiological properties of laughing gas; the application of electricity to chemistry, with the consequent isolation of the alkali metals; a more exact knowledge of the halogens and the halogen acids, and, standing quite apart from any of his researches, the safety lamp. Davy was a brilliant experimenter, bold and quick in execution, somewhat hasty in his conclusions and not very much of a speculator. We owe no far-reaching theory to his genius, but we are indebted to him for opening up a new branch of chemistry. For this electrochemistry which he was the first to cultivate has

since his day broadened sufficiently so that we have, on the one hand, theories of chemical action intimately related to electricity, and, on the other hand, many applications of electricity in the chemical industries.

Davy's talents remind one of another countryman of his, Sir William Ramsay. Both were geniuses in the laboratory; both worked rapidly; both were not always painstaking, but rather quick in execution and sometimes hasty in deduction. Compared with their brilliant qualities as experimentalists, the theoretical background of both was weak. Neither is the author of any profound theory. Both belong to the "dashing" variety of scientist—to what Ostwald calls the "romantic" type.

Davy was born in Penzance, England, in 1778. Like many chemists of English stock, his early training seems to have been anything but systematic. At a somewhat later age he was apprenticed to a local apothecary and here he picked up much miscellaneous information. But what, of course, really counted was that the gods had endowed Davy with what we call genius; and the genius was of the chemical variety; and the apothecary's "shop" was where this genius could find some play. He read Lavoisier's "Elementary Chemistry" and he began experimenting with the primitive tools available to him. Then came the opportunity which allowed this genius to blossom. In Bristol there was a "Pneumatic Institute" which had for its object the investigation of the medicinal effects of various "gases." "Gases" were fashionable ever since Priestley and others had discovered them; and people began to wonder whether the physiological effects of such gases might not be of some value; hence arose the Bristol Institute. But the more important event was that Davy, at the age of twenty, was offered a position in this institute.

Davy had scarcely established himself in Bristol when he began his experimental work on "gases." One of these, "diminished nitrous air," was first prepared by Berthollet in 1785 by heating ammonium nitrate; and now Davy investigated its properties. Among other things, he inhaled the gas and found that it was not only non-toxic but acted much like a stimulant, arousing pleasurable feelings. Southey, the poet, whose acquaintance he had made, also inhaled some of the gas, and he wrote: "When I took the bag from my mouth, I immediately laughed. The laugh was involuntary, but highly pleasurable, accompanied by a thrill all through me, and a tingling in my toes and fingers, a sensation perfectly new and delightful." Experiences such as Southey's suggested the name "laughing gas," though the chemists of our day call it "nitrous oxide." But Davy made the important observation that inhaling nitrous oxide deadens pain; and he described this property in connection with a bad toothache, the pain of which "almost diminished after the first four or five inspirations." We must also thank Davy for a very careful chemical analysis of nitrous oxide, which he accomplished by burning charcoal in the gas, measuring the nitrogen that was left after combustion and calculating the oxygen from the carbon dioxide produced. If our system of atomic weights and our modern nomenclature were used, Davy's analysis would lead to the formula N_2O for nitrous oxide; which is, as a matter of fact, the accepted formula for the gas.

Davy's work attracted the attention of Count Rumford, who had recently laid aside his own notable researches in physics to found the Royal Institution in London. Rumford offered the post of chemical lecturer to Davy at the new institution. Davy accepted. Within twelve years Davy became the most celebrated chemist in England, and the Royal Institution became known wherever science flourished. It is this same institution that Faraday, Dewar

and Bragg have worked since the time of Davy.

It was in 1790 that Volta produced an electric current by means of the voltaic pile, and it was some eleven years later that Nicholson and Carlisle decomposed water by means of the electric current. Davy was very much impressed with the possibilities of the electric current. He had an intuition that the application of electricity to chemistry would yield valuable information as to the chemical make-up of bodies. With this in mind, he built himself a battery "containing 24 plates of copper and zinc 12 inches square, 100 plates of 6 inches, and 150 of 4 inches square, charged with solutions of alum and nitric acid"; and he immediately attacked the problem of the nature of the caustic alkalis.

In a very general way, the alkalis were looked upon as elementary substances, though there were some vague questionings on this point. Davy had his doubts, together with others, and he hoped that his battery might be of some service in settling the question. He first passed the current through a solution of potash; in this experiment he merely succeeded in decomposing the water without affecting the potash. He next used fused potash and was more successful, particularly when he used the electricity as a heating agent (to fuse the potash) as well as for the purposes of decomposition.

> A small piece of pure potash was placed upon an insulated disk of platina, connected with the negative side of the battery, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower there was no liberation of elastic fluid; but small globules having a high metallic luster, and being precisely similar in visible characters to quicksilver, appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained, and were merely tarnished, and finally covered by a white film which formed on their surfaces."[1]

Not only did Davy, in this manner, show that caustic potash was a compound, and that an element, potassium, could be isolated from it, but he showed that what was true of caustic potash was likewise true of caustic soda; that the latter, like the former, was a compound, and that by means of the electric current an element, sodium, could be isolated from it. This work was, in turn, followed by an exhaustive examination of the alkaline earths and by the ultimate isolation of the elements barium, calcium and strontium.

Davy was now in the full bloom of intellectual vigor. No sooner was he through with the alkalies and the alkaline earths than he turned his attention to another puzzling problem of the times: the elementary nature of chlorine. Ever since Scheele's discovery of the gas there had been doubts as to whether chlorine was an element or a compound, and the weight of opinion seems to have been in favor of regarding the gas as a compound. Berthollet, for example, regarded chlorine as an oxygen compound; and even Gay-Lussac looked upon the gas as an oxide of an imaginary metal. Davy's powerful voltaic battery and the success he had had in using it to determine the elementary nature of substances suggested to him that the battery might be applied to elucidating the nature of chlorine. All attempts to decompose chlorine failed. Even when acted upon by charcoal heated to whiteness by the voltaic battery, no decomposition took place, suggesting that the persistent belief that chlorine contained oxygen had no foundation in fact. After many experi-

[1] For this quotation, as well as for a number of others, I have to thank Professor T. M. Lowry, who, in his book "Historical Introduction to Chemistry" (Macmillan), has made an exhaustive study of original material.

ments Davy was led to the conclusion that

> the body improperly called oxymuriatic acid has not yet been decompounded; it is a peculiar substance, elementary as far as our knowledge goes, and analogous in many of its properties to oxygen gas. It has been judged most proper to suggest a name founded upon one of its obvious and characteristic properties—its color —and to call it "chlorine."

Davy also busied himself with two other halogens: iodone and fluorine. Iodine was discovered by Courtois in 1811 and its properties were very carefully investigated by Gay-Lussac and Davy. Again making use of his battery, Davy assured himself that iodine could not be decomposed. "In its specific gravity, luster and color, it resembles the metals; but in all its chemical agencies it is more analogous to oxygen and chlorine." He, indeed, proposed the name "iodine" for it. While fluorine was not isolated until much later—in 1886, by Moissan—Davy did recognize that both fluorspar and hydrofluoric acid contained such an element, and he even attempted to isolate it by passing an electric current through hydrofluoric acid—a modification of which method was successfully used by Moissan.

Davy was now—in 1812, when thirty-four years old—at the very height of his fame. He was easily the most famous, and, incidentally, the most popular chemist in England; and, with the exception of Berzelius, probably the most talked about chemist in all Europe. In this year he was knighted and within three days of his knighthood he married a rich widow. From now on Davy becomes Sir Humphry Davy, rich and prominent socially; and from now on he becomes less and less active, scientifically. He undertakes a tour of Europe on the grand scale. He meets Gay-Lussac, Berthollet, Cuvier, Humboldt and Volta. He is accompanied by a young man who sometimes acts as his secretary and sometimes is made to do the work of valet, particularly when Lady Davy is around. This young man had received an appointment as assistant to Davy at the Royal Institution, and his name is Michael Faraday. Davy returns to England, delivers popular lectures at the Royal Institution, works a little in the laboratory, but not so very much, writes a little, but not so very much, meets all the lords and ladies of the realm and all the literary gentlemen of the kingdom, and eventually succeeds Joseph Banks as president of the Royal Society. But in the meantime he has invented one thing for which the miner will forever bless him—the Davy safety lamp. And in the meantime his health, never particularly robust, has taken a turn for the worst. He takes frequent trips to Europe, usually alone, because, it would seem, his wife brought him money rather than happiness. In 1829, in the course of one of these European trips undertaken primarily to improve his health, he arrives in Geneva, and never leaves the place again. There Davy died in the same year, and there he was buried.

EXTENT OF PERSONAL VOCABULARIES AND CULTURAL CONTROL

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In view of the fact that language is so fundamental in human affairs, it provokes much less attention than might be anticipated. We are surrounded by a medium of culture of which language is the vehicle as fish are surrounded by air or land animals by the atmosphere, and yet the vast majority of human beings are quite as unaware of this contiguous stratum as animals are of that which impinges upon them. After a type of animal developed which had sense, mentality enough to turn round upon its environment, inspect it, draw inferences about it, great interest was taken in its study and important results therefrom ensued.

Just how language sprang into existence no one knows exactly, but there is an abundance of theories concerning it. There is considerable agreement that close to the beginning of human life pantomime played a large rôle and was the chief mode of passing on information. Hunters, warriors and adventurers came back full of their exploits and had to give expression to them in some way. To-day a man turns loose a barrage of words and relieves himself of the tension. Then, in default of words, he had to gesticulate, imitate his former actions, represent by attitudes and postures, describe situations by means of graphic movements. It is supposed that in the excitement of this portrayal grunts and cries which may have accompanied the original activities were expressed. Probably a part of the mimicry of the situation one was trying to depict consisted of the imitation of sounds by vocal expressions. Ultimately the various kinds of sounds came to have a somewhat definite meaning and could be used apart from pantomime as signs of meaning. And after ideas could be communicated by sounds and descriptions given, these utterances would undergo a development. They would differentiate, grow in number, become more definite and so come to be an oral tongue or language. With the evolution of human society through savagery, barbarism and civilization words multiplied, syntax and grammar emerged, writing and printing came to crystallize forms of speech and embalm them in human memory. Travel and trade greatly augmented the number of terms and when science developed a still greater extension of words and terms took place.

Some one has given rise to a theory of language which is a reverberation of that early period of human life when physical effort was such a pronounced and vital part of carrying on communication. It centers on the idea that language is primarily oral with us, that it is vocal, made up of sounds produced by the manipulation of the vocal organs. We can not produce sounds without making an effort to work our organs of speech in just the right way. As a consequence of the effort we make to talk, we have a lively memory of the attitudes, adjustments, and movements of the vocal organs we experience in talking. So it comes about that our memory of words is largely a memory of the physical adjustments and efforts accompanying talking and that when we are listening to some one talking we are trying all the time to reproduce the muscular adjustments of vocal organs necessary to produce the words we hear. And beyond

this, we are intently scanning the facial movements of the speaker and interpreting the muscular activities rather than the sounds registered in our ears.

Human beings are enveloped by a medium on which they are dependent for getting a living and adjusting themselves to others. This is culture or the cultural surplus. This culture is not the academic stuff, that infinitesimal portion of all extant knowledge which college boys and girls get during their few years sojourn in academic halls and are told represents the *sine qua non* of existence. It is the totality of all the ideas, inventions, plans, ways of doing things, customs, manners, codes, institutions, sciences, arts and whatever men's minds have brought into existence during the whole course of social evolution that have continued as a part of the social environment. This cultural surplus, beginning as a tiny trickle hundreds of thousands of years ago in the nascent society of eolithic man, becoming a sluggish brook among paleolithic men, a small river with neolithic men, has incremented more and more rapidly during later culture epochs and with torrential rapidity during the last century until to-day it envelops all civilized individuals in sea-like embrace. It ought to go without saying that what we call civilization is the culture surplus in its highest and most recent reaches and that were the culture increments of the last few centuries exscinded, higher civilization would be removed and such civilized life would be impossible.

Since this cultural surplus is so tremendously important, its control or use must be, of course, quite as important. In fact, it is by the employment of this culture in multitudes of ways that the work of the world gets done and the satisfactions and joys of life get accomplished. It is significant to realize that the avenue of access to this culture and the central, fundamental agency for its manipulation are unobtrusive and immaterial symbols: *words, vocabularies.* As culture grows, the number of words multiply accordingly. Mr. Karl Voghto estimates we have added 250,000 to our language since 1900.[1] The extent of our knowledge of words is a measure of the degree of our participation in the civilization of our age. The proof of this is of a very evident sort. If we think and know in symbols and only by the use of symbols, and if all the symbols we employ are words, either heard or seen, then we can have a knowledge of civilization and its accomplishments and undertakings only to the extent that we command a knowledge of the words and symbols by means of which the culture of our age is represented. Knowledge is the avenue to an understanding of the universe at large and of the human, social world with which we are most intimately associated. The child or the man who commands slight knowledge can have only the vaguest adumbration of the significance of either. Individual intelligences graduate upward from that point through larger and larger ranges of knowledge until the most gifted or cultured minds are reached—the minds which have a fairly adequate comprehension of our social and material worlds. But so far as we know, the only depositories our minds have for knowledge are words and symbols in the form of words.

The extent of one's vocabulary and the accuracy of the estimate made of it are both dependent upon the validity of the method employed in making the count. In consideration of this fact, it may be well to devote some attention to the question of methods.

Probably the oldest method is that which builds an opinion concerning the number of words a given person knows on counting the different words contained in his writings. Following this device, the students of Shakespeare's works have assigned a vocabulary of twenty-four thousand words to that

[1] *Popular Science Monthly*, January, 1929, page 48.

famous writer and those of Milton's works have found that the blind bard made use of seventeen thousand words. The numerous writers of the English Bible all together had to content themselves with handling only seven thousand two hundred words. But they lived in very primitive times for the most part and we could not use our standards of judgment on them. However, in the case of all publicists, it is to be remembered that the number of words they know is undoubtedly very much greater than they use in their writings; and that even the number of words they are capable of using is much more extensive than that appearing in their published works. It is interesting to note that some one has made a reckoning—how good a one it is impossible to say—that the late President Wilson knew over seventy-two thousand words. This estimate was made on the basis of the addresses and papers he produced during the war together with his earlier published works. And as we shall see later, the estimate of this large number is probably not only not exaggerated but is entirely too conservative. It is likely that Woodrow Wilson knew twice that number.

There have also been attempts, largely in the nature of pure guesses, to judge the extent of vocabularies of the rank and file of people. There are statements to the effect that Italian grand opera singers employ only about six hundred words, that the words used by many peasants number still fewer, being only three or four hundred, and that the vocabulary of persons above the average contains not more than three thousand or four thousand words. We must regard these as only rough and entirely inadequate guesses, for it is certain that primitive peoples who live in a much lower stage of culture than grand opera singers and peasants have considerably larger vocabularies.

A knowledge of the extent of vocabularies of primitive people throws a good deal of light on the subject under discussion. It furnishes a background on which to form a judgment concerning the capacities of peoples a great deal more advanced. If the daily spoken language of a savage folk is a matter of ten thousand words, what should be that of an enlightened people, and more especially that of those persons placed at the summit of the highest cultural attainment? We certainly should expect a developmental expansion of considerable moment.

There have been many dictionaries of primitive peoples compiled by missionaries and philologists. It is, therefore, quite within our power to make an estimate of the number of words in their lexicons. In these primitive vocabularies there are few or no dead and obsolete words, for, in nearly all cases, there was no written language and all the words the investigators collected were those which were in current use by the living men and women making up the groups. The chances, therefore, are that most of the adults of the group were in command of the bulk of the words constituting the vocabulary. According to Kroeber, the following are the number of words contained in the vocabularies of some primitive peoples: the Aztec Nahuatl, 27,000; the Central American Maya, 20,000; the Plains Dakota, 19,000; the African Zulu, 17,000; the Navaho of our Southwest, 11,000; the Klamath of our Northwest, 7,000. The range of culture of these groups is from upper barbarism to upper savagery. If the vocabulary of savages ranges from seven to nineteen thousand words and that of barbarians ranges still higher, what should be the extent of the vocabulary of the average civilized or enlightened Frenchman, German or Englishman? Undoubtedly it must be a multiple of the other.

There have been formulated in recent years certain standardized modes of estimating the number of words in any given person's vocabulary. One of these is the Terman test, which was devised in the

following fashion. From a dictionary containing eighteen thousand words, which are supposed to be the most common ones, was made up a list of one hundred words selected by taking the last word of every sixth column of the dictionary. This method of selection would prevent the operation of bias or prejudgment. Now the one who wants to test his vocabulary selects from the hundred words those which he can fairly well define. The resulting number is multiplied by 180. Did one know all the hundred words, his resulting vocabulary would be eighteen thousand. Did he only know one half of the hundred, his vocabulary would be nine thousand words. Upon applying the standard test to himself, the present writer found he has a vocabulary of 16,833 words. This is between one seventh and one eighth the number obtained by the method to be described later in this article.

According to the results obtained from the application of this test to a large number of persons, some average or general conclusions were obtained. A person eight years of age knows 3,600 words, one of ten knows 5,400, one of twelve knows 7,200, one of fourteen knows 9,000, the average adult knows 11,700, and the superior person knows 13,500. Using the test on college students, it was found that male students know the following number of words: Freshmen, 9,240; sophomores, 10,860; juniors, 13,040; seniors, 12,700. The vocabularies of female college students according to the same order of classes are: 8,860; 9,325; 10,130, and 10,700.

The general method of random or arbitrary sampling of the phenomena to be measured employed here in the selection of the basic list of one hundred words is scientifically correct. It is the method commonly used by scientific statisticians in their study of phenomena of every kind. A sample that is large enough and arbitrarily chosen is found to be an accurate representation of the whole realm of phenomena of which it is a part. Nevertheless, we are inclined to regard the Terman test as coming short of the results which such a test should attain. It probably understates the extent of the vocabularies of the persons to whom it is applied. It seems likely that the dictionary of eighteen thousand words is much too restricted and that consequently the multiple applied to the known words is not nearly large enough. Were the same method of sampling applied to an unabridged dictionary and a multiple applied which was adjusted to the size of the lexicon, the results would unquestionably be much more competent.

It should be clear by this time that one's estimated vocabulary is largely the outcome of the kind of method used in making the estimate and of the limitations imposed in the use of the method. Thus there are several bases for making an estimate which, if employed, would yield widely different results or sizes of vocabulary. There are: the ability to define words, the ability to use words irrespective of the ability to define them, knowing words for reading but not for speaking or writing purposes. The resulting vocabularies will vary in size in the order of the bases named.

The extent of the dictionary employed in formulating the standard or in making the test should be sufficiently extensive to provide for the inclusion of two very essential items: first, the technical vocabularies of professional persons, like doctors, lawyers, chemists, engineers; second, of business men, such as merchants, manufacturers and managers. A professional man or a technician has a knowledge of thousands of technical terms used in his calling in addition to the usual vocabulary of educated persons. As a sample of this I find that the manager of a Woolworth store in a city of twenty thousand inhabitants must know and have at his tongue's end the name of all the five thousand articles

contained in the store. Many of these articles are, of course, common articles which every one would know. But a well-equipped practitioner possesses a store of many thousands of technical scientific terms which are unknown to the laity. Second, it should include, also, the words built up on the foundation of certain basic words by a process of compounding through the use of prefixes and suffixes. Such words usually do not appear at the left margin in the columns of unabridged dictionaries, or at the foot of the column; consequently they are liable to escape inclusion in samples and so are not allowed for in multiples. Thus from the word *abolish* are built nine other words by the addition of suffixes. From the word *accent* are derived ten additional words. *Accept* gives rise to six and *access* to seventeen. Then by the use of prefixes twenty other words are added to the fifty-four so far derived from the four original words, altogether a total of seventy-four words. One gets the force of this method of multiplying words relatively to the size of one's vocabulary by supposing that the person in question knows five thousand words of the basic sort from which it is possible to build up other words. The average number of words built from the four words cited above was eighteen. Multiplying 5,000 by 18 yields a total of 90,000, the enlargement to the number of words the individual pretty certainly knows because he knows the foundational ones. This is a purely suppositious case, and instead of five thousand we might need to substitute four thousand, three thousand, or some other number. It certainly would not do to multiply one's entire vocabulary by such a multiple as 18 because much of the vocabulary is made of proper names, historical, geographical, and personal, which are not generally subject to taking on prefixes and suffixes.

It has been apparent to the writer of this article that there is a great surpise in store for any one who will make an elaborate and painstaking investigation of the extent of his own vocabulary, using as the basis of such test one of the great unabridged dictionaries of the English language. If he has hitherto looked up to Shakespeare as the consummate master of the language in all the phases and regarded himself as a mere pigmy in his knowledge of words when compared with the score and a quarter thousands Shakespeare is said to have made use of, his pride in himself will swell enormously after he has completed the self-investigation. Not that it will be demonstrated that he can utilize a greater number of words in writing or speaking than that great master of drama, but only that he really has a knowledge of a very much greater number of terms than the former is known to have employed in his written productions. The short description of some results the present writer has obtained in this field will give a semblance of veracity to these statements.

The statements I have read concerning the extent of vocabularies known or used by humans served to make me quite curious concerning the exactitude of the results and methods used to obtain them. Many of the estimates seemed to be no better than mere guesses and the results secured by some very good tests appeared to fall short of those which might have been attained had other methods been employed. Consequently I undertook to make a test of the extent of my own vocabulary, that is, of the number of words I can fairly claim to have some considerable knowledge of.

The dictionary employed in making the test is the Standard unabridged of 1922. This lexicon contains 2,737 pages, each page containing three columns of words. The words of these columns appear in two different situations: those

heavy type words set even with one another at the left margin; and non-marginal words, such as synthetic and compound words, and many proper names, phrases, etc. One kind of synthetic words is built out of such more elemental words as accent, abolish and the like by annexing prefixes or suffixes. Another kind is made by compounding some marginal word with other words.

The first estimate concerned the marginal words. It was conceived that if enough columns to fill fifty-two pages, or an average of two pages for each of the twenty-six letters of the alphabet, were examined, a sample sufficiently large would be obtained to be representative of all the columns of the lexicon. However, it seemed more scientific to select columns under each letter in the proportion each such letter's number of columns bears to the total number of columns. This gave to such letters as *x* and *z* only a part of a column and to such as *c*, sixteen, and to *s*, seventeen columns; but no letter was assigned less than one column. The particular columns to be employed under each letter were chosen by the hit-and-miss plan in order to secure purely arbitrary and random sampling, thus obviating personal bias. Then the words about which I knew much or considerable were marked, the total number of words in the column were counted, and the results were tabulated column by column until the total 159 columns had been covered. The total number of words counted was 4,019, the number known was 1,150, 28.66 per cent. It was estimated from the average number of words per column counted that the dictionary contains about 209,000 marginal words. It was assumed that if one knows 28.66 per cent. of the large sample of over four thousand words, he will know the same proportion of the 209,000 words. In this case the number of marginal words known was 59,800.

Since a full explanation has been made of the method used to secure an estimate of the proportion of known marginal words contained in the dictionary columns, it will be sufficient to state that the same general method was followed in securing an estimate of the known words of all the non-marginal terms. The editors of the Standard indicate that the particular edition used to make the test contains 450,000 words. We noted that the total number of marginal words amounted to about 209,000. This would leave about 241,000 of the non-marginal kind. The percentage of words of this kind which were known was found to be 28.2, or almost the same as the proportion of the marginal sort. Applying this percentage to 241,000 yields the total number of this kind of words that are known, which was 68,000. And now totaling the two estimates, 59,800 and 68,000, we have a grand total of 127,800 words known.

In consideration of the other estimates that have been made in the past, this number seems enormous. Some may be inclined to discredit the estimate altogether. Before doing this, however, let the reader observe two cautions: First, take the time to give the method used here a fair test by applying it to himself. It is likely that then he will be satisfied that this estimate may not be far wrong. Second, then consider that a large number, probably far the larger number, of known words are forms or derivatives of more elemental words. Think of *circum* in combination with a lot of other elementary words whose root meanings are known, resulting in *circumvent, circumscribe, circumambulate, circumlocution,* etc., etc. Then recall such a word as *accent* and what derives from it: *accent, accentuation, accentual, accentualist, accentually, accentuality, accentuate, accentuable, accentuation, accentus.* It is pretty certain that if one knows *accent* about all the other forms

of that word are known. And what is true of these forms of words is also true of compound words and of phrases.

So far, I have been able to induce only two persons to apply this test to themselves. It requires much time and persistence, so that few have the requisite scientific curiosity to carry it out. But fortunately, two of my very mature students, graduate men in their thirties, have made estimates. One used a Practical Standard Dictionary containing 140,000 words. He selected two pages under each letter of the alphabet by the hit-and-miss plan for counting purposes. He found he knew 2,055 of the 4,368 words contained in the fifty-two pages employed, or 47 per cent. This yielded a total of 65,800 words out of the 140,000. Had he employed an unabridged dictionary, the number he knew might have been considerably swelled.

The other student made use of an unabridged Standard dictionary of 2,757 pages. He considered both marginal and non-marginal contents. His estimate of known words in the entire dictionary was 52,489.

It is noted that the vocabularies of the students are only about half as large as the vocabulary of the first estimate. Perhaps this difference may not appear as evidence of the incompetency of the method when it is known that the one who made the first estimate has been a student during a rather mature life-time and has a command of languages the others do not possess. But one must expect variations even in the estimates made by those of about the same degree of culture because of the fact that there is no absolute criterion of the degree of knowledge which is to be applied in selecting the words which are to be considered as known. Two persons might have the same knowledge concerning a given word and one would class it among his known words and the other among his unknown words. This is a difficulty which it would be hard to overcome. Nevertheless, it is probably not a very important difficulty.

TROPICAL MEDICINE[1]

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JUST what is tropical medicine? Why should people in these United States be interested in such a thing and especially what does it have to do with California and the Pacific Coast and the Pacific Ocean? To answer these questions is to bring up one of the most romantic and interesting fields of human activity which has found a place in modern life. Medicine means more than giving drugs. In fact, drugs have a rather small part in it. Medicine means the prevention, cure and alleviation of disease. The proof of the correctness of this definition is to be found in Webster. And when we qualify this by saying tropical medicine, we mean simply the prevention, cure and alleviation of disease in warm climates. That is a subject big enough, important enough and withal sufficiently spiced with human interest, romance and practical necessity to engage the attention of every person, no matter what his creed, education or politics. All that makes for health preservation and prevention or cure of disease in hot climates comes within the realm of tropical medicine. And then, when we remember that in California especially we have all the essentials of a tropical climate and that many diseases ordinarily considered tropical are found native to this state, we can see that the subject of tropical medicine comes very near home.

In India sacred Mother Ganges receives the devotion of untold millions of her dusky sons and daughters. They come by the hundreds of thousands to bathe in her waters and worship at the thousands of temples bordering her muddy shores. In Benares, the Holy City of Hind, one sees these hordes, men, women and little children, bathing, drinking, immersing themselves and taking carefully home to their own villages earthenware vessels of the sacred water. Then the scientific Westerner looks closer at the sacred water itself and sees dead dogs, cats and rats floating in it. He sees a vilely dirty, sluggish river receiving the sewage and garbage of great cities; the half-burned remnants of the many funeral pyres on its banks; the effluvia of millions of diseased humans, and its filthy flood he finds to be a warm teeming culture medium transmitting disease in wholesale quantities to these misguided but undoubtedly sincere worshipers. That is why cholera, plague and many another disease also call the Ganges "mother" and here is found one of the world's sources of untold disease, corruption and suffering.

These Hindus do not believe in disease. They do not believe that anything in this world is material or other than illusion and, as a result, they, their children, their friends, neighbors and all with whom they share their cherished earthenware vessels of sacred water from the Ganges go down to death from preventable, unnecessary diseases, which Western science has largely eliminated by study of the natural history of the germs and parasites which cause these diseases, and by means of medically inspected milk and water supply. But the religious beliefs of the populace are an insurmountable obstacle to doing such things in India except to a very limited degree. In fact, the British in India find themselves in somewhat the position of the forty-niner who got the grizzly by the tail and dared not let go. Native superstition, tradition, religious

[1] From the Pacific Institute of Tropical Medicine.

belief—all are deadly foes of sanitary improvement. Education comes slowly. The fight of tropical medicine to prevent preventable disease, to cure curable disease and to alleviate all disease is waged against tremendous odds. This, to be sure, adds to the glory of the combat and leads the forces of science to offer many a sacrifice of brilliant men and devoted women. But it also postpones the day when mankind shall profit by the knowledge now available making for better health, happier human lives and more efficient industrial enterprise. These obstacles, of one kind or another, found in all tropical countries, are a constant lure to the adventurous, lending glamour and romance accompanied by deadly peril to the work of tropical medicine in tropical climes.

In the memory of our fathers, yellow fever was a terrible danger, invading the United States even as far north as Philadelphia and devastating the country with death and ruin in its wake. Commerce stopped. Cities were ruined. The rich and the poor alike fled unsuccessfully from "Yellow Jack." Then, in 1900, came the epochal experiments of the Army Yellow Fever Commission in Cuba, supplying proof that "Yellow Jack" was carried from victim to victim in only one way—by the bite of certain species of mosquitoes. Dr. Carlos Finlay and a few others had suspected this for many years. Drs. Lazear, Carroll, Agramonte and Reed proved it beyond a cavil. They and the brave volunteers who submitted to infection were medical heroes and some became martyrs. Then the late Dr. Hideyo Noguchi after long experiments in South America believed that he found the exact germ which caused yellow fever. But last year Noguchi and three other physicians, working fearlessly in the tropical heat of Africa, found that the cause was not yet discovered and laid down their lives as the price for knowledge which now seems to open the way for the real conquest of "Yellow Jack." For several years medical sanitation and scientific mosquito control seem to have eradicated the disease from the Western world where its stronghold had before seemed impregnable.

But in the last two years a great and unsuspected source of yellow fever has been found in West Africa, where several varieties of monkeys have been found to be susceptible, and it seems probable that a great animal reservoir exists from which the contagion spreads to man. The disease reappeared last year in Brazil, and a similar situation may also prove to obtain in South America.

An instance of how an ancient and dangerous disease has deserted cold climates and become truly a tropical disease is seen in the case of leprosy. Today leprosy is rampant across tropical Africa and is wide-spread in nearly every tropical country. Our knowledge of leprosy has advanced along two lines recently. First, effective treatment is possible, so that the active stages can be relieved and the disease arrested. This by allowing patients to be returned to their homes and occupations does away with the terrible hopelessness of leprosy. Second, leprosy is apparently a soil infection contracted through cuts and abrasions of the skin and, while many persons are infected, in the majority it lies dormant just as in the case of tuberculosis. It is thus not contagious from man to man unless under very exceptional circumstances.

There are many great tropical diseases which do not occur endemically in cooler climates but which from time to time may invade the United States or be carried over in patients from the infected regions. Kala-azar, the black fever of China and India, is one of these. It is caused by a microscopic

animal parasite which invades the blood and tissue cells. It is curable by proper treatment. It is carried from man to man by a species of sand-fly. A first cousin of this parasite causes Oriental Sore, so common in the Near East and around the Mediterranean.

African sleeping sickness, which has no relation whatever to what is called sleeping sickness in the United States, is caused by a microscopic animal called a trypanosome which invades the blood stream and central nervous system. It has depopulated vast areas in central Africa and made it impossible for man or animal to live there. These are illustrations of the enormous practical need of tropical medicine and its great importance to-day in warm climates.

In the jungles and rice-fields of many lands insect life swarms in unbelievable abundance. Among these insects, as, for example, mosquitoes, biting flies, sand-flies and ticks, are to be found the carriers and intermediate hosts of many dangerous maladies which are best combated by attacking these so-called vectors through sanitary engineering, protected water and food supplies, insect quarantine and means of avoiding bites. In no other field of medicine are so many specific cures and effective treatments known as in tropical medicine.

We in California are far from being isolated from tropical diseases. We vie with the Ganges, Turkestan, the Trans-Baikal and a spot in Africa in having a focus of bubonic plague in our ground squirrels. Human cases of plague have occurred in California each year since 1908 which were due to this source of infection. Malaria is still a factor in public health in this fair state. Rocky Mountain spotted fever is found and also the plague-like rabbit disease called Tularemia, named after the Tulare swamps where it was first identified. We have many of the numerous forms of fungus infections so common in the tropics. One of these, coccidioidal granuloma, is similar to tuberculosis and is more common in California than anywhere else in the world. In the realm of intestinal parasites we are also well supplied. Amebic infections are common and many first cousins and relatives. Round worms, tapeworms, leaf-like worms, as well as hookworm, trichina of uncooked pork and even rare tropical filarial infections are often seen. Pellagra, scurvy, beriberi and sprue claim their victims. So that altogether California is a fair field in itself for the practice of tropical medicine. Its position as the western gateway to the Orient and the Pacific islands and its increasing commercial relations with Spanish America serve to increase the variety and abundance of exotic diseases already present.

No disease that ever afflicted mankind can exceed in its toll of death, suffering, invalidism and wrecked nations and civilizations the ravages of malaria. This disease is still the major enemy in the tropics and entitled to be called the "Captain of the Men of Death." From the mangrove swamps and paddy fields of the equatorial belt to our own southern states and west to California, malaria is a pestilence that walketh in darkness, borne by more than thirty kinds of anopheles mosquitoes. Greece and ancient Rome fell before its sway. Its cost in lives and money to-day is stupendous and the problem of its control is far from solved. Sanitation has accomplished wonders in special localities but alone is insufficient to meet the need. Sanitation and mosquito control are terrifically expensive, and the world needs nothing less than the complete eradication of malaria before warm climates will be safe for human work and living.

Dysenteries are caused by many different agents, but the largest groups are due to the dysentery bacilli and to

amebas. Both of these are frequent in the United States, and bacillary dysentery is often seen in children. Undulant fever was originally called Malta Fever because it was discovered in the Island of Malta, where it was caused by germs in the milk of infected goats. It is wide-spread now over the United States, especially on farms and in rural communities. Its germ is transmitted in goat's milk to a minor degree, in cow's milk and by hogs. Milk which has been pasteurized or which is produced in properly inspected dairies is safe. Undulant fever somewhat resembles typhoid and may persist in recurring waves for six months and even a year. Such diseases as infectious jaundice, rat-bite fever and relapsing fever appear from time to time in the United States.

It is hardly realized that rabies (hydrophobia) is wide-spread and dangerous in nearly all tropical countries. This is due to the fact that most native races see no sense in control or care of dogs, which consequently run wild and are usually diseased and half-starved. In Hindu and Buddhist countries especially no dog may be killed, even though no one feeds or cares for it. Under these conditions dog-bite is common and human rabies is a frequent result. Nearly every large tropical city has its Pasteur Institute engaged in the manufacture of the Pasteur treatment which prevents rabies. To these centers people come by the thousands from many miles around. Even in China rabies has been known since early historic times. The only means of prevention known after an infected bite is by the Pasteur treatment. These institutes also manufacture anti-venins against snake-bite and various vaccines and protective sera. Their influence is wide-spread. The value of their ministrations is attested by the great demand on the part of native populations, who know all too well the dangers of these diseases, from rabies to smallpox, and who really and pathetically appreciate the opportunity of avoiding them.

Problems in untold numbers of disease prevention and health preservation in the Orient and in hot climates are fascinating, practical, new and awaiting solution. Nowhere else do achievement and human service offer greater inducements than here. The scientist in nearly every line is concerned. The nurse, the laboratory technician, the builder, engineer, statesman, administrator, business man, missionary, soldier, sailor, traveler—each and every one has a vital stake in the struggle of tropical medicine to make hot climates safe for man and to make man safe to go into hot climates after their treasures of wealth, experience, science and travel.

Man, doubtless, began his activities on the earth in regions corresponding in warmth to the present tropics. For two reasons he moved away from these languorous lands. In the first place, the hardier, more roving and more intelligent of mankind were led, among other things by their curiosity, to seek cooler localities where, thanks to a tougher fiber, they survived. This more resistant, energetic and adaptive portion developed under the stimulus of changeable climate and the need for securing food and shelter under more difficult conditions. In the second place, insects, poisonous animals, snakes, fungi, bacteria, protozoa and a host of other enemies of man also developed in the warm moisture of the tropics and thus the mass of disease causes became rank and luxuriant so that man could not rise above them. All his racial energy was spent in trying to maintain mere existence, leaving none for intellectual and spiritual progress. But the contest was unequal and tropical man either died out, migrated or remained savage.

To-day, recognizing this old historical record, man is faced by a population in

temperate climates beginning to approach the limits of available food supply. He needs more room for living purposes, more food, more power, more of the innumerable luxuries and necessities associated with culture and intellectual improvement. All these things may be had, one way or another, in the low altitudes of the tropical belt. Therefore, almost instinctively, we are turning to tropical enterprise and development, facing squarely the great problem as to how the tropics can be made safe for civilized man and developed to produce what he needs for still further advancement.

So true is this trend, so clear the need in the eyes of commerce and statecraft, that we find great institutes of tropical medicine established as centers for the education of physicians and nurses, for study of special problems of medical and commercial importance and for treatment of patients. Such is the splendid Tropical Institute of Hamburg, supported by the German government. Here in this great, flourishing German port is a splendid tropical hospital, research plant and school for physicians. Such is the excellent and, in this country, little-known Tropical Institute of Amsterdam supported by the Dutch government as a necessary adjunct for its great colonial empire in the East Indies. Such also the institutions in Paris, Brussels and Rome.

England has four schools of tropical medicine. Of these the largest and best is in London, where twice a year a class of seventy-five physicians spends five months in the graduate study of tropical medicine and hygiene. Near the London school is the wonderful Wellcome Museum of Tropical Medicine, a remarkable teaching exhibit which illustrates graphically with charts, photographs and specimens of its ravages, the cause, transfer, geography, symptoms and epidemiology of each tropical disease. Such a museum is a splendid nucleus for the teaching of any science, especially tropical medicine. London lives by the sea and its vast sailor population requires a series of hospitals in which all manner of tropical maladies are constantly seen.

In the tropics are many splendid medical centers and hospitals. The United Fruit Company has an unexcelled system of hospitals in the ports of the Caribbean Sea. The Canal Zone and its excellent hospitals administered by the U. S. Army Medical Corps are well known. The Oswaldo Cruz Institute for Medical Research is one of the outstanding features of Rio de Janeiro. Cairo with its hundred-year-old hospital of eight hundred beds is a noted center for wide-spread modern methods of disease control. In addition to the clinical care of patients carried on in the medical stations of the Hadassah movement throughout Palestine, the Hebrew University of Jerusalem is turning out excellent scientific studies. The best medical school in the Near East is at the American University of Beirut.

Bagdad has an excellent hospital, research plant and Pasteur institute, and is opening a medical college. In India there are numerous centers of first-class medical work. The crown of them all, however, is the Calcutta School of Tropical Medicine, founded by Sir Leonard Rogers. This school is unexcelled in the world. It has an unusually able faculty and a large tropical disease hospital. Its service to patients is very large. Twice a week some three hundred lepers come to the leper clinic alone where they are rapidly made non-infectious, so far as possible kept at regular employment, allowed to live with their families and are treated like human beings.

Rangoon, Colombo, Singapore and Kuala Lumpur in Malaya are outstanding for their medical facilities and ser-

vice. Space allows only mention of the various centers in Australia and in Java. Manila has wonderful facilities and material, largely centered in the Bureau of Science and the University of the Philippines. The great Culion Leprosy Station is a monument to American medical science and is being made a memorial to General Leonard Wood. Two millions of dollars are now being raised to make this station wholly adequate and to allow the fullest advances in treatment and prevention of this ancient enemy of man. No more worthy enterprise is before the American public to-day. Professor David P. Barrows, of the University of California, is among the best-informed Americans to-day on Philippine and Pacific Ocean relations. His endorsement and leadership of the Leonard Wood Memorial Fund speaks for itself.

Honolulu, with its modern and complete Queen's Hospital, has an excellent, though small, center for study of tropical medicine. China, the future arbiter of the Pacific, has in Shanghai the medical department of the Central Nationalist University and in Peking the Rockefeller-endowed Peking Union Medical College, both of which are leading in the great field of disease control in China.

So we come back to the United States and find several universities on the east coast developing strong departments of tropical medicine, such as Harvard, Columbia and the Johns Hopkins. Tulane University in New Orleans devotes much attention to this important subject. Everywhere commerce, business and government are recognizing that more and more mankind must live in close relation with, if not in, the tropics.

Until recently there was no center on the Pacific Coast for this type of work. Now in the University of California there has been established the Pacific Institute of Tropical Medicine at the Hooper Foundation in San Francisco. This is in close association with the University Medical College, but is a separate graduate school. The Tropical Institute of the University of California is organized for three types of work.

(1) Regular courses in tropical medicine and hygiene are given for physicians. Young doctors going out to commercial stations, government service or missionary work in the tropics or the Orient can here secure training in the specialized kind of problems they will have to face. Practicing physicians in those countries can here secure a complete and up-to-date review. (2) Research is carried on in connection with tropical diseases and hygiene, problems arising from shipping and passenger traffic, cargo spoilage and contagious diseases on shipboard. Special studies are being started on tropical drugs and in connection with tropical food supplies. (3) Facilities are provided for the diagnosis and treatment of patients suffering with any kind of tropical, Oriental or exotic disease. In addition to these features, classes are available for non-medical persons intending to live or travel in the tropics or the Orient. Here special instruction is given in simple language on health preservation, personal hygiene and disease hazards in those places.

The stories of Herman Melville, Captain Cook's voyages and the works of Alfred Russell Wallace are literary classics which afford an insight into many practical problems of tropical medicine. It is no small job to avoid sickness in a ship's company, and when contagious disease appears on shipboard difficulties multiply. Yet, no sane person wants to travel on a ship where there is not adequate provision for proper handling of such emergencies. International and United States quar-

antine requirements must be met. These all have to do intimately with tropical medicine.

Quarantine to-day is designed to operate with as little impediment as possible to commerce and passenger traffic. By observance of definite scientific rules, delays are avoided and disease is not introduced. The splendid national quarantine system of the United States, conducted by the federal Public Health Service, is responsible for the fact that in the past generation cholera and yellow fever have been unknown in this country. Smallpox, leprosy and plague are equally well excluded, but unfortunately these diseases are already endemic in the United States.

Enough has been said to give some idea of the scope and importance of tropical medicine to the world to-day and especially to the west coast of the United States. The preservation of health and the treatment and prevention of disease in hot climates hold a lure for the student, the physician and the scientific worker that is exceeded only by their practical importance for the average citizen.

THE SIGNIFICANCE OF BOUNDARY CONDITIONS IN PHYSICS

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THE expression of physical laws in differential form is one of the most fundamental features of theoretical physics, and a discussion of the meaning of this process should always form an important part of the foundations of the subject. A number of points arise over which the beginning student is rather apt to be puzzled. Not the least significant of these is the following question: why is it that the general solution of a partial differential equation in physics is so seldom of concrete use to the physicist? To understand the meaning of this question more precisely let us consider the time-honored case of a transversely vibrating string. Applying the usual dynamical analysis to a differential element of the string we obtain the usual second order linear partial differential equation of motion. The general integral giving the displacement from its equilibrium position of any point of the string at any time is then found to be of the form $f(ct-x)+F(ct+x)$, where x denotes distance measured along the string from some chosen origin, t is the time and c is a definite function of the tension and linear density of the string; finally f and F are two perfectly arbitrary functions of the arguments in the parentheses. Mathematical examination of this result then shows that there is wave motion along the string in both directions with velocity of propagation equal to c. But surely we do not need a mathematician to tell us that if we shake a string waves will move along it! We can see that without the mathematical analysis. The only specific thing we learn from the general solution is the dependence of the velocity on the physical properties of the string. How can we obtain more concrete information about the string's behavior? Evidently only by assigning certain special conditions which the general solution must satisfy. These are the so-called "boundary conditions." Let us look into their fundamental nature and their meaning in physical problems with some detail.

Continuing our study of the string we see that we can at once render the problem more specific if we confine ourselves to motions which are simple harmonic in time. The functions f and F entering into the solution are then restricted to the circular type (*i.e.*, sine or cosine). But even the imposition of this restriction fails to specify the answer to the question which in a case of this kind the physicist feels bound to ask: *viz.*, at any instant of time what is the exact state of motion of every part of the string? For the solution still contains four arbitrary constants or parameters. To specify these, further conditions are necessary involving assumptions as to the state of motion at some definite point or points of the string at some definite instants of time. The reader will recall that two of these constants may be fixed by the assumption that the string has a finite length and that no motion ever takes place at the ends. The final answer to the physicist's question becomes possible only when we have the following additional information, *viz.*, an instantaneous photograph or snapshot of the whole string at some initial instant, as well as the velocity with which every part of the string is moving at that instant. Incidentally the assumption of

rigidly fastened ends leads to another important result: it says that the possible frequencies of free oscillation (*i.e.*, the oscillation resulting when the string is struck or plucked and then let go) are limited to a discrete series—the so-called harmonics. We need not go into further details about this well-known problem, but may summarize by noting that the introduction of the boundary conditions into its general solution has accomplished for us the following three noteworthy things: (1) specified the type of mathematical function to represent the physical disturbance; (2) evaluated the arbitrary constants appearing in the expression for this disturbance; (3) introduced a certain characteristic discreteness into the resulting motion. It is just these things which are necessary in the answer to the physicist's desire for concrete knowledge, as expressed in the question stated.

The above simple illustration makes it evident that the boundary condition concept is an extremely significant one in the development of mathematical physics. It is perhaps worthy of more extended study and a consequent extension of meaning over the restricted use generally current in physical literature. It is thus the purpose of this article to interpret the concept in the broadest possible sense to see what unifying light it casts on the subject of mathematical physics as a whole. Proceeding from this point of view we shall divide such conditions into two classes, the specific and the general. A specific boundary condition is simply a postulated physical event in space and time, expressed by the requirement that a certain physical quantity shall have a definite value or set of values throughout a certain region of space within a certain interval of time. This definition includes the well-known "initial" conditions of classical physics and absorbs them into our more extensive concept. On the other hand, by a general boundary condition we shall mean any fundamental restriction on the type of behavior of a physical system, expressible by means of a mathematical relation among a set of physical quantities characteristic of this system. It may thus be itself a physical law but is more apt to be a general condition which all possible physical laws for a given system must satisfy, thus transcending the special laws. We have in mind here such fundamental postulates as the quantum conditions in atomic structure theory and the requirement of invariance with respect to transformations of coordinates so prominent a feature in the relativity physics. These are not generally emphasized as boundary conditions, but we shall see that there is a certain gain in unity of thought by so considering them.

For the moment let us give some attention to the specific type of condition. From the mathematical standpoint there is perhaps nothing very striking about this type. Specifying a set of events in space and time yields a system of equations from which the arbitrary constants of the general solution of an appropriate differential equation can be evaluated. But from the physical standpoint it seems that rather more is involved. For the necessity of the boundary condition tells us that in order to predict the future behavior of a physical system we must know not only the differential law according to which the system changes its state: we must also have definite knowledge of its state at a certain specified time or at any rate some property of the system expressible by a set of physical events. It is only where such knowledge is available that the concept of causality has any practical significance in physics. One more well-worn example suffices to emphasize this point. From the fundamental dynamical laws and the law of force we are able to compute the position of any particle in a central force

field at all times past or future (and incidentally the type of orbit traversed) as soon as we know its position and velocity at any single instant; neglecting the practical difficulties in the reduction of observations, we have here the theoretical basis of all calculations of astronomical tables. Other illustrations of like character will occur to the reader.

This is a good place to focus attention on a large class of problems peculiarly noteworthy because of our ignorance of the appropriate conditions. Consider a mass of gas, which from the standpoint of the kinetic theory is assumed to consist of an enormous number of molecules moving in straight lines in every direction with varying velocities, colliding frequently with each other and the walls of the confining vessel. It is postulated that each molecule is a rigid sphere and that its motions are governed by the ordinary laws of collisions in mechanics. It would seem a comparatively simple matter in principle though perhaps time-consuming in practice to compute the position and velocity of each molecule from the above assumption. But we are forgetting the boundary conditions! In order to make these calculations we must know the state of the system of particles at some definite time. This is, however, a hopeless task. We simply can not hope to know exactly the boundary or initial conditions in a case like this where the number of entities is so great. What then do we do? In such a problem we invariably fall back on probability considerations. We cease to fix attention on the individual member of the aggregate and concentrate on the average, employing the principle of "large numbers," *i.e.*, the method of statistics. The fundamental meaning attached to the employment of probability in physics is thus intimately bound up with our knowledge or ignorance of boundary conditions. Thus, according to Poincaré, in our consideration of the behavior of any physical system, we may distinguish three degrees of ignorance: the first, in which we know both the laws in accordance with which the system changes and the appropriate boundary conditions, and hence in all strictness have no need for probability save what our laziness suggests; the second, much more common, in which we know the laws but are ignorant of the conditions (as witness the above example), and the third, in which we know neither the laws nor the conditions. As a matter of fact, no physicist ever remains content with this third degree of ignorance; he always proceeds to postulate possible laws to which probability calculations may be applied in an effort to understand the phenomena in question. So we may really consider as an important element in the distinction between a dynamical theory and a statistical theory the possibility of assigning definite boundary conditions in the former case and the practical impossibility of carrying out this step in the latter case.

Boundary conditions of this type are obviously closely connected with the possibility of measurement (whether real or ideal), for fixing an event for physical purposes implies observation and measurement. If the event in question deals with an enormous number of entities we are naturally led to feel that although the measurements specifying the conditions may be carried out in principle the task is too complicated and involved to be of practical utility. Interestingly enough this matter is receiving considerable attention in the more recent atomic structure theory. The fruit of the endeavor to inject more concreteness, greater "Anschaulichkeit," into the matrix quantum mechanics has been Heisenberg's "principle of indeterminism," which states with ruthless definiteness that we can not hope to carry out to indefinite precision the measurements fundamental to the fixation of the boundary conditions even in principle, no matter how small the number of entities may

be. Putting the matter specifically, suppose we wish to measure the position of an electron in an atom with great exactness. According to the principle we are then forced to sacrifice precision in measuring its velocity, *i.e.*, we must remain content merely with the probable value of the latter, or with the probability that the electron shall have a velocity lying in any assigned interval. Thus the principle maintains that it is impossible to measure both the position and the velocity of an electron simultaneously with the same degree of precision. It is clear that acceptance of "indeterminism" in this sense puts our ignorance of the necessary boundary conditions in the atomic domain on a quite different basis from the probability considerations we have just been discussing. There the disregarding of the boundary conditions and the reversion to the study of average behavior were the dictate of economy, convenience and simplicity. Here, however, our procedure is to be governed by necessity. In admitting that even when one particle is under consideration we can never know the boundary conditions necessary to a complete knowledge of its behavior in space and time, we are proceeding from the state "ignoramus" to the greater extreme "ignorabimus" (du Bois-Reymond). The physicist is bound to ask himself the question, is such a procedure calculated to advance the science? To embark even on a beginning to the answer to this question would carry us too far into the complexities of quantum mechanics. But no matter what our attitude may be toward the "indeterminism" principle, it must be admitted as an interesting illustration of what our conception of boundary conditions in microscopic phenomena may eventually become.

So far in our study of specific boundary conditions we have confined ourselves to discrete events, such as the position or velocity of a system at some definite instant. But this is not the only case of interest. Boundary conditions need not be discrete but may cover a continuous range. Consider a fiber which is twisted from its normal equilibrium configuration by the application of torque. When released it displays the familiar phenomenon of elastic fatigue and hysteresis. But this means that a knowledge of the state of twist and angular velocity of the fiber at any instant is not competent to enable us to predict its state and motion at any subsequent time. To answer the usual question here we must know the whole history of the fiber since first it began to move at all, *i.e.*, we must be acquainted with its heredity. The boundary conditions in this case must thus extend over continuous intervals of space and time. The name hereditary mechanics has been given to the field of problems into which such conditions enter. It is obviously only by means of an integral extended over the lifetime of the system studied that such a boundary condition can be expressed mathematically. Thus it is that integral equations have come to be of great service in physics.

There is a large class of extremely important physical problems which involve the flow of energy across the interface of two media. We here encounter a kind of boundary condition which is different from the specific type we have just been discussing. Thus at the interface we find it necessary to postulate a certain continuity for the functions representing the disturbance which is being propagated. It is not that we specify the exact values at the boundary; rather certain relations must hold among the physical quantities characteristic of the disturbance in the two media at the boundary. Hence we may look upon this type of condition as more general. Thus, to seek a simple illustration, when a sound wave traverses a tube in which there occurs an abrupt change in cross-section, we require that at the place where the change occurs there shall be

continuity in the pressure and the volume displacement of the air disturbance. This assumption leads to the correct experimental value for the fraction of the incident sound energy which is transmitted across the junction. Situations essentially not at all different are met in the behavior of light and all electromagnetic radiation at an interface. The imposition of the continuity conditions serves to fix the distribution of energy in the reflected and transmitted beams. As a matter of fact, often more than this is involved: the familiar law of refraction (*i.e.*, the law of Snell) for an obliquely incident beam can be shown to follow from the mere fact that some condition must subsist at the boundary and is independent of the precise form of this condition.

In the above illustration, then, we have an example of the general boundary condition, namely, a fundamental restriction on the type of activity possible for the system considered. Thus when wave energy passes through a region, just as soon as a boundary is encountered, the propagation of the disturbance is profoundly modified. In place of, let us say, a single progressive plane wave in one direction we must now have waves in both directions (or in certain cases, in every direction); the whole motion pattern is altered, and all as the result of the continuity condition associated with the presence of a boundary. Exactly the same kind of thing is met in the case of the vibrating string when the ends are fixed. For the condition of no motion at the ends is precisely a continuity condition at a boundary, though of a special type. Incidentally, this condition is peculiarly important, because as we have seen in our example, it serves to introduce discreteness into the motion by limiting the possible frequencies of simple harmonic vibration to a certain definite series of values, the so-called "characteristic values." The general problem of which this is a special case has long had a particular charm for mathematicians; it is only within the past three or four years that it has assumed unusual importance for physics with the advent of the wave mechanics in atomic structure. For in the recent theory of Schrödinger the possible states in which an atom may exist are represented by the solutions of a certain wave equation (not dissimilar in form from that of a vibrating medium, like a string, but differing from it in the interpretation of the quantities involved) satisfying the boundary condition that they shall remain finite, continuous and single valued throughout all space and be zero at infinity. It then develops that, as a result of this condition, the principal parameter of the equation, representing the energy of the atom (and corresponding to the frequency in the analogous problem of the vibrating medium) is in general restricted to a discrete set of values. In the cases so far studied, these values are precisely the correct energy values indicated by experiment for the possible stationary states of the atom. It is difficult to resist the feeling that the discreteness introduced by the above boundary condition is intimately connected with the discreteness which we ought to expect to be physically characteristic of an atomic mechanism, and which is indeed one of the most striking experimental facts about all atomic phenomena. It is improbable that the final physical interpretation has been given to either Schrödinger's wave equation or the boundary condition restricting the solutions. But no one can question the tremendous importance of this boundary condition to the final result, and so it marks a definite extension in the significance of this conception in modern physics.

It is indeed true, as the reader who is familiar with the history of recent atomic theory will recall, that the classical Bohr theory of the atom employs a boundary condition which achieves essentially the

same end as the boundary condition of the Schrödinger theory, with, of course, distinctive differences in details which have seemed to favor the latter. To be specific, it will be remembered that the Bohr theory postulates that in an atom the electrons move in accordance with dynamical laws, but from the whole continuum of possible mechanical orbits it selects as actually existent those only for which certain path integrals of the component momenta are equal to integral multiples of the fundamental constant of Planck. Here again discreteness is introduced into the problem. The energies of the stationary states of the atom are the energies of the orbits which are allowed by the quantum condition, which is thus really just as much a boundary condition as that which must be satisfied by the solutions of Schrödinger's equation. Physically the former does not seem to be so understandable as the latter, but this means merely that we are not so familiar with conditions involving path integrals of momenta as with conditions involving continuity at a boundary in a medium, with which we have dealt throughout classical physics. But in any case the significant fact is that the desired result is secured through the agency of a boundary condition.

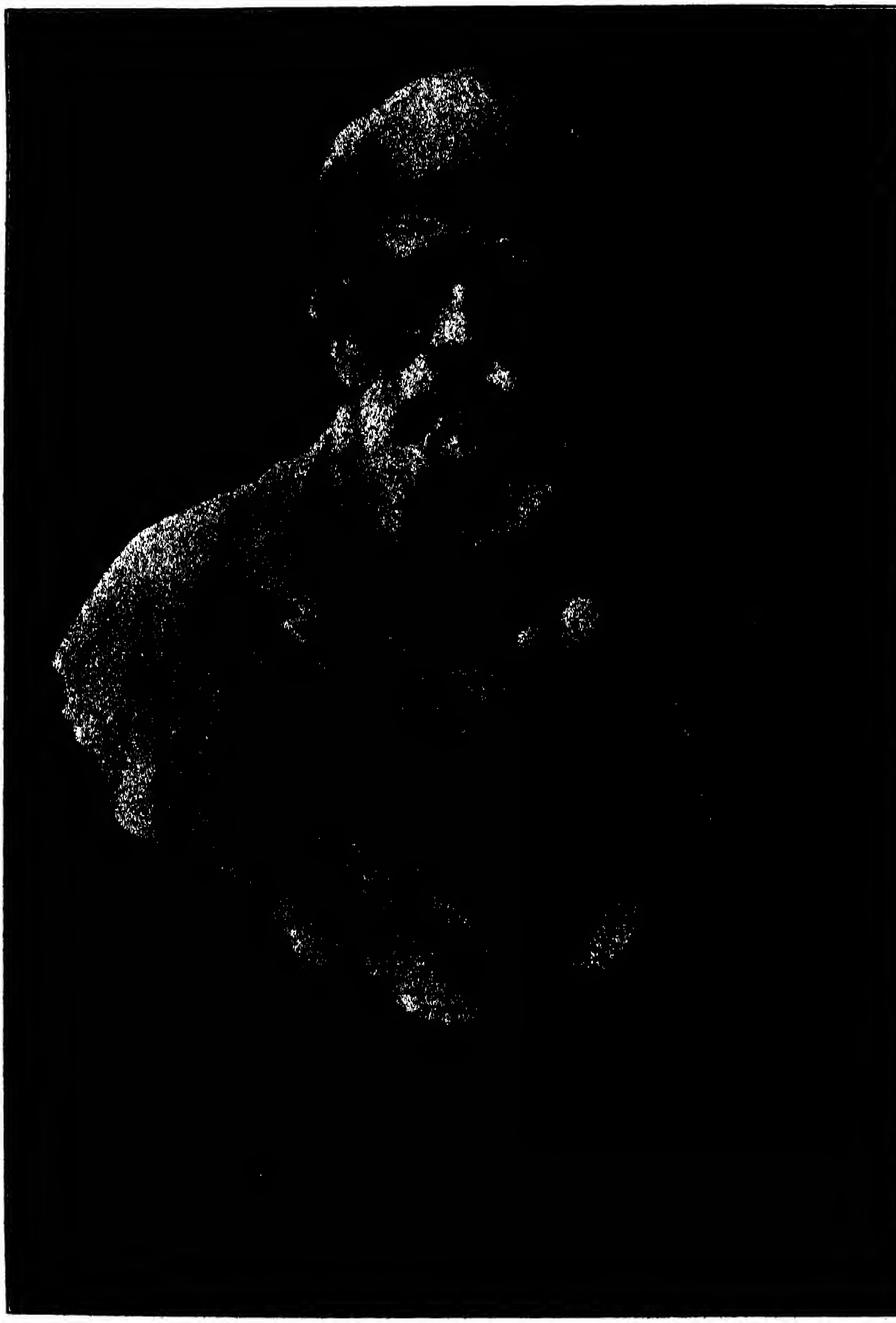
Added interest in this subject is provided by the theory of relativity, for it is through this that we may see our way to an even more general view of the nature of boundary conditions. Concomitant with the growth of this theory there has arisen the conviction that physical laws in general must be of such a character that they retain their form intact when the coordinate system in which the various quantities are expressed is transformed to another system in accordance with the now celebrated Lorentz-Einstein transformation equations, which is only the formal mathematical way of expressing the impossibility of detecting absolute motion by any means and in addition the fact that the velocity of light has the same value for any two coordinate systems moving with respect to each other at constant velocity. In the broad interpretation of this essay the invariance with respect to the Lorentz-Einstein transformation is just as truly a boundary condition as is the quantum condition. It has, to be sure, a more general scope than the latter, for it serves to select the type of physical law which is best adapted to describe successfully physical phenomena. Of still greater generality because of its larger realm of applicability is the fundamental postulate of general relativity that all physical laws must be expressed in the form of tensor equations. Here again the restriction is on the type of general law and not merely on the particular kind of behavior resulting as a special case of a given law. In this sense boundary conditions like the tensor requirement are more general than the differential equations in which the laws of physics are embodied. In truth, it would seem as if physicists were coming to realize more and more the importance of ascertaining the general boundary conditions which whole groups of physical laws must satisfy. This puts us in a position where the possible type of law is of greater significance than the specific laws themselves. From the esthetic point of view this marks a tremendous gain for science as a whole. Nor is it without utility, as is illustrated by Einstein's use of it in the discovery of the general law of gravitation.

The reader should be able to suggest to himself many other illustrations, but to render the matter as clear as possible, it is well to point out that in the view of the present article many so-called physical laws are really boundary conditions in disguise, as it were. Thus the law of the conservation of mechanical energy appearing as the first integral of the equations of motion of a conservative dynamical system is a boundary

condition in the sense that it is the mathematical expression of the fact that the system under consideration is conservative; it thereby delimits or fixes a boundary for the class of systems considered and separates them from all others. The importance of this step becomes clear when we find that many of the specific laws obeying this general condition are found to be satisfied approximately in the world of physical phenomena. And the notion of the separation of dynamical systems into conservative and non-conservative systems has been of prime importance in the advancement of theoretical mechanics.

Perhaps the most recent application of our general view is the introduction of the group concept into atomic physics by Weyl and others. This concept, in accordance with which a set of entities is said to form a group with respect to certain operations provided certain definite conditions are satisfied, has long been of unifying utility in mathematics. Its application in atomic structure theory may prove the means of providing much desired uniqueness in quantum mechanics, in ascertaining the most general types of rules under which the behavior of all atomic systems may be subsumed.

How then may we sum up the whole matter? We may say that closely associated with every physical law there are to be found important boundary conditions of both a general and a specific nature, and forming a very significant part of the physical meaning of the law as well as its practical application. The specific conditions show us how to use the law to predict physical events, and ignorance of them forces us back on probability considerations; the general conditions fix the possible types of laws or the possible kinds of functions which enter into them. The mind can conceive countless forms of differential laws. The general boundary conditions serve to pick out the useful ones. Our search should forever turn in the direction of these conditions, the discovery and clear statement of which represent the forward development of mathematical physics.



CHARLES DARWIN

BUST PRESENTED BY DR. JOSEPH LEIDY, II, OF PHILADELPHIA, TO THE BRITISH NATION, IN MEMORY OF THOSE AMERICAN NATURALISTS WHO CAME TO THE SUPPORT OF CHARLES DARWIN UPON THE PUBLICATION OF "ORIGIN OF SPECIES" IN 1859.

THE PROGRESS OF SCIENCE

THE PRESENTATION OF DOWN HOUSE TO THE BRITISH NATION

THE formal opening of Down House, the home of Charles Darwin, presented by Mr. Buckston Browne, a distinguished surgeon and student of Huxley, to the British Association for the Advancement of Science in custody for the nation, was observed under the auspices of Sir Arthur Keith, F.R.S., on June 7, in the presence of a large and distinguished audience.

Inaccessible either by rail or bus, Down, situated among the chalky uplands of Kent, has remained peaceful and unspoilt. It is as Darwin knew it, and now his own home, a fine English country house on the outskirts of the village, has been restored as nearly as possible as it was when he lived and worked there.

In the study in which Darwin wrote the "Origin of Species," there is to be seen the exceptionally high chair in which he sat, using as a desk a board placed across his knees. In the center of the room is his work-table and among the relics displayed on the book shelves are his pistols, the telescope he used during the voyage of the *Beagle,* his geological hammer and many other scientific instruments and the proverbial snuff jar. To the list of treasures there are to be added the fifty-eight original Darwin letters, known as the Müller collection, which Dr. Henry Fairfield Osborn, a former president of the American Association, is presenting to Down House.

Down House lies in the midst of beautiful gardens and orchards, and it was on the lawn that the opening ceremony was performed.

Mr. Buckston Browne formally presented the house into the keeping of the British Association.

Sir William Bragg, F.R.S., president of the British Association, accepted the gift, expressing the gratitude of the association.

Sir Arthur Keith, F.R.S., delivered the principal address, in the course of which he said:

> In Down House was enshrined the personality of a great man, one who always placed goodness above greatness. It is right that we should stress now this personal aspect of Darwin's life, for the character of no man has been so wilfully travestied in his own century as well as in ours.

Dr. R. Anthony, who occupies the chair of the immortal Cuvier, represented France and presented the felicitations of French science.

Dr. Joseph Leidy, II, as the representative of the American Association for the Advancement of Science, presented a magnificent bust of Darwin by the gifted sculptor, Charles L. Hartwell, R.A., now on exhibition in the Royal Academy. He referred to the interesting fact that from American science came the first foreign official recognition of the "Origin of Species" upon its publication in 1859, when the Philadelphia Academy of Natural Sciences made Darwin a corresponding member upon the recommendation of Joseph Leidy and Isaac C. Lea.

Upon the announcement of his election, Darwin wrote Sir Charles Lyell, "It shows that some naturalists there do not think me such a scientific profligate as many think me here."

In the course of his remarks Dr. Leidy said:

> We wish therefore to forge still stronger the chain which links American science with Down House and this memorial.
>
> It is our great privilege to place in this shrine the fine bust of Charles Darwin as a gift to the British nation from America in memory of those American naturalists who came to the support of Charles Darwin upon the publication in 1859 of the "Origin of Species."

DR. N. L. BRITTON
DIRECTOR-IN-CHIEF OF THE NEW YORK BOTANICAL GARDEN FROM 1896 TO 1929

DR. BRITTON AND THE NEW YORK BOTANICAL GARDEN

THE resignation of Dr. N. L. Britton as director-in-chief of the New York Botanical Garden was an event of the first importance in the botanical world and in scientific circles generally. This resignation, dated May 25, 1929, was accepted at special meetings of the board of managers and the scientific directors of the garden, held on July 8, 1929, and took effect as of August 1, 1929.

Dr. Britton was one of the prime movers in the plan to establish a botanical garden in New York City. The garden was incorporated in 1894, and on July 1, 1896, Dr. Britton entered upon his duties as the first director-in-chief, having been secretary of the board of managers for some two years preceding that date.

When the new garden was established there were only three independent botanical gardens in the United States, namely, the Missouri Botanical Garden, at St. Louis, the Arnold Arboretum, near Boston, and the U. S. Botanic Garden in Washington. At that time the general public had very hazy ideas as to what a botanic garden is, and one of the problems of the new director was to educate the lay public and, in particular, the officials of the city of New York, as to the nature, importance and needs of such an institution. In addition to this, a quite undeveloped area of two hundred and fifty acres had to be laid out, graded and planted; buildings, greenhouses and public conservatories were to be planned and erected, and, most important of all, a scientific staff had to be organized, and botanical collections assembled for scientific and educational work.

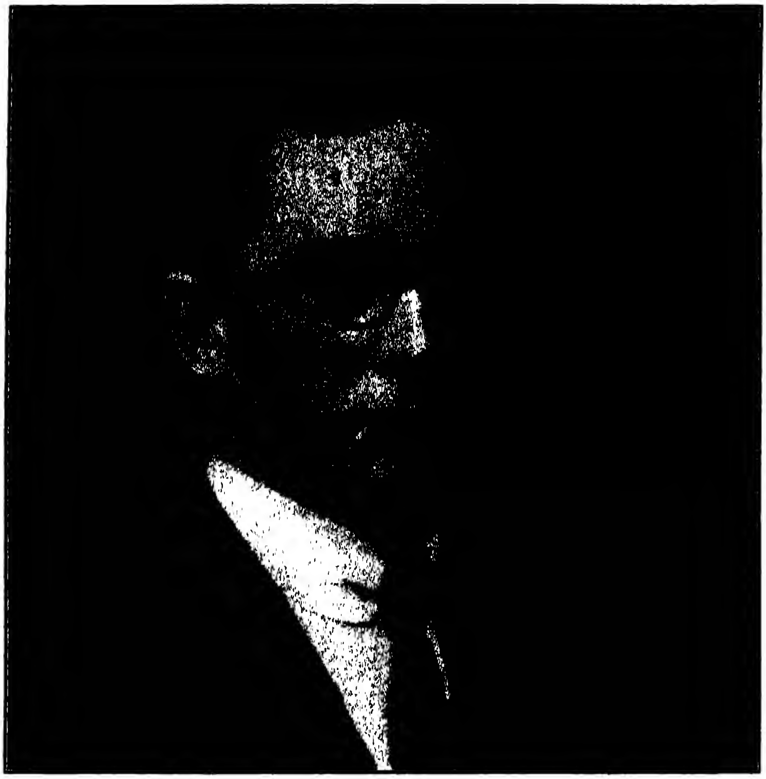
For such work something more is needed than a knowledge of plant life, and the officials of the new garden were exceedingly fortunate in having, in the person of the first director-in-chief, a man who was not only an accomplished botanist, but also an engineer and an able scientific administrator.

Pari passu with the development of the physical plant, a vigorous program of scientific research was initiated, with emphasis on systematic botany and botanical exploration in North America, especially in subtropical and tropical America and adjacent islands.

Within a very short time "New York Botanical Garden" came to mean one of the largest and strongest organizations of botanical investigators in America, and the affiliation of the garden with Columbia University favored the early registration of a large number of graduate students.

The results of research by staff and students required facilities for publica-

THE NEW YORK BOTANICAL GARDEN. MUSEUM BUILDING.



DR. ELMER D. MERRILL

WHO SUCCEEDS DR. BRITTON AS DIRECTOR-IN-CHIEF OF THE NEW YORK BOTANICAL GARDEN

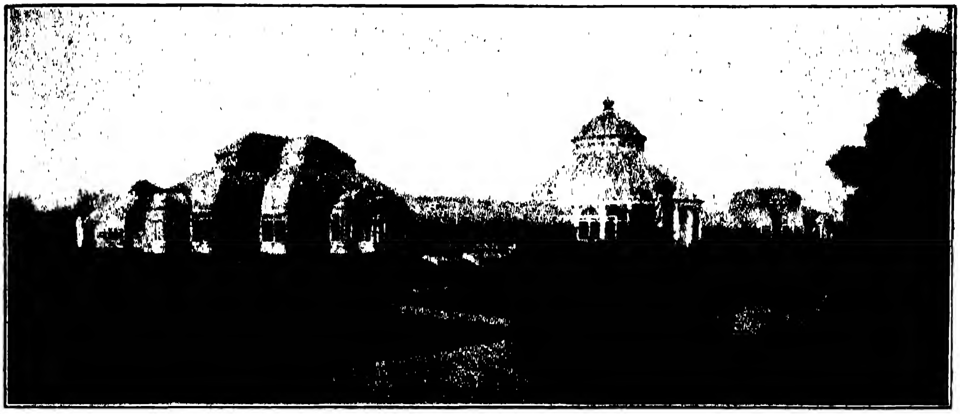
tion in addition to those already available, and this need has been met by the establishment of several serial publications which have taken their place as among the most important of the botanical world.

As a result of the extensive program of botanical exploration, and in other ways, the herbarium of the garden, comprising not less than 1,500,000 specimens, has become one of the largest and most important herbariums in the world, rich in type specimens and other valuable material. The garden library, of some forty thousand volumes, is one of the most important botanical libraries in the New World.

Under Dr. Britton's able administration, the New York Botanical Garden soon took its place among the foremost institutions of its kind, serving the local public to an extent far in excess of the public's share in the cost of maintenance, and making voluminous and substantial contributions to botanical science.

At the celebration of the twentieth anniversary of the foundation of the garden, September 6 to 11, 1915, one hundred and forty-five botanists and others were in registered attendance and many messages were received congratulating the garden and its director-in-chief on the splendid accomplishment. Volume VI of the Memoirs of the New York Botanical Garden comprises thirty-six scientific papers presented as a part of the anniversary program.

On May 7, 1919, the board of managers gave a complimentary dinner to Dr. Britton at the Metropolitan Club,



ONE OF THE CONSERVATORY RANGES OF THE NEW YORK BOTANICAL GARDEN.

New York. The guests included the scientific directors of the garden and a number of other distinguished representatives of botany and other sciences. On this occasion a loving cup was presented to Dr. Britton, bearing an inscription that the cup was presented "in recognition of his distinct services to the Garden, public education, and science." The then president of the board, Dr. W. Gilman Thompson, announced that the dinner was not given in celebration of any event or anniversary, but solely as an expression of the good-will, esteem and confidence of the board of managers.

The appointment of Dr. E. D. Merrill as director-in-chief, in succession to Dr. Britton, will take effect as of January 1, 1930. In the interim, Dr. Marshall A. Howe, a member of the original staff of the garden, and for some years assistant director-in-chief, will be acting director.

Professor Elmer D. Merrill, who will succeed Dr. N. L. Britton as director-in-chief of the New York Botanical Garden on January 1, 1930, is a native of East Auburn, Maine. After graduating from the University of Maine in 1898 (with honorary degrees of M.S., 1904, and Sc.D., 1926), Dr. Merrill held various appointments in George Washington University, the University of Maine, the United States Department of Agriculture and the Insular Bureau of Agriculture, the Bureau of Forestry, Bureau of Government Laboratories and Bureau of Science, Manila, P. I. From 1919 to 1923, Dr. Merrill was director of the Bureau of Science and associate professor of botany and head of the department, Philippines, 1912 to 1917, with the title of professor, 1917 to 1919 and professorial lecturer, 1919 to 1923. Since 1924 he has been professor of agriculture and director of the Experiment Station, University of California, and director of the California Botanic Garden since 1927. From 1906 to 1923, Dr. Merrill was editor of the *Philippine Journal of Science* and editor of *Hilgardia* from 1925.

Professor Merrill is a member of the National Academy of Science, the Société botanique de France, the Botanische Gesellschaft and the Royal Asiatic Society, as well as numerous American scientific societies. He is a recognized authority in the systematic botany of China, Philippines and adjacent islands, and comes to the New York Botanical Garden richly acquainted with the important scientific administrative duties of that position.

C. S. G.

DEDICATION OF THE CHEMISTRY BUILDING AT PRINCETON UNIVERSITY

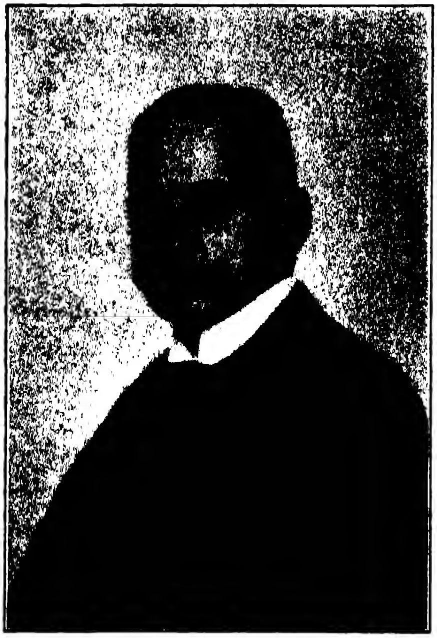
Distinguished scientists met at Princeton, New Jersey, September 26, 27 and 28, 1929, to attend the dedication of the new laboratory, and to be present at the international conference on catalysis and the mechanism of chemical reactions.

At 12:30 P. M., on September 26, the academic procession marched to the auditorium of the laboratory, and, following the singing of "America," Charles Z. Klauder, the architect, presented the symbolic key of the building to President Hibben. Mr. Klauder pointed out that one prominent feature of the laboratory is the centrally located stockroom.

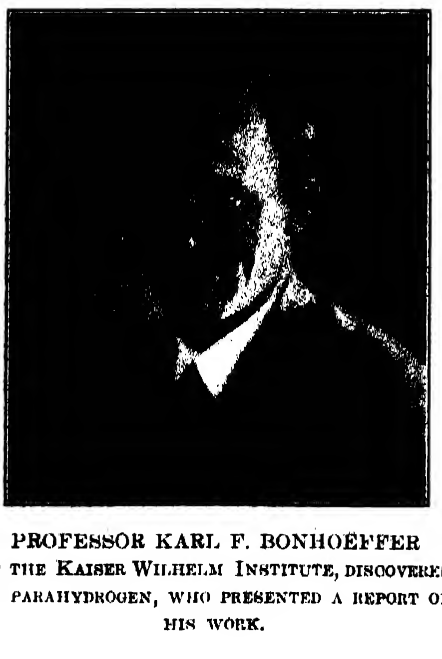
President Hibben accepted the key for the university, saying that the laboratory would not be justified if the university had not had at its disposal the recently completed fund of 3,000,000 for research in pure science, and if it did not have men capable of conducting excellent research.

Professor Hugh S. Taylor, chairman of the department of chemistry, then delivered the chief address. He said that the successive laboratories at Princeton had covered the whole epoch of modern chemistry, and closed his address as follows: "We are indeed fortunate here that ways have been devised to ensure close cooperation between the sciences and, by reason of that cooperative effort, we are drawing ever-increasing numbers of students to our graduate schools from all parts of the world. We commend especially to the parents and guardians of our Princeton undergraduates a serious consideration of the rich opportunities for scientific training which Princeton now offers in contrast with earlier decades, and we

THE NEW CHEMISTRY BUILDING AT PRINCETON



PROFESSOR MAX BODENSTEIN
DIRECTOR OF THE INSTITUTE OF PHYSICAL CHEMISTRY AT THE UNIVERSITY OF BERLIN, WHO PRESENTED HIS WORK ON CATALYTIC OXIDATION OF AMMONIA.



PROFESSOR KARL F. BONHOEFFER
OF THE KAISER WILHELM INSTITUTE, DISCOVERER OF PARAHYDROGEN, WHO PRESENTED A REPORT OF HIS WORK.

bespeak their counsel and encouragement to their sons seriously to consider the opportunities to which they are heir. In return for their labors we offer them a life in science rich in its satisfaction, full, scholarly and enduring. *'Non est mortuus qui scientiam vivificavit.'* "

At the close of Professor Taylor's address the honorary degree of D.Sc.

PROFESSOR M. POLANYI
OF THE KAISER WILHELM INSTITUTE, WHO PRESENTED A PAPER ON ATOMIC REACTIONS IN HIGHLY DILUTE FLAMES.

(Doctor of Science) was conferred by the university on the following visiting chemists: Professor Max Bodenstein, director of the Physikalisch-Chemisches Institut, Berlin, Germany; Professor F. G. Donnan, F.R.S., University of London; Sir James C. Irvine, principal of St. Andrews, Fife, Scotland; Dr. Irving Langmuir, assistant director of the research laboratories, General Electric Company, Schenectady, N. Y., and Professor Jean B. Perrin, director of the Laboratoire de Chimie-Physique, Paris.

The exercises were concluded by Dean Robert R. Wicks, of the University Chapel, who pronounced a prayer and benediction, and by the singing of "Old Nassau."

The guests were entertained at luncheon at the Princeton Inn, and in the afternoon the ladies of the chemistry department held a reception in the library of the laboratory.

On the evening of the same day Professor F. G. Donnan, of the University of London, gave a public lecture on "The Application of Physical Chemistry to Chemical Industry with Special Reference to Catalysis."

The Chemical Laboratory and equipment cost over $1,500,000. In addition to offices and laboratories of faculty members, it has nine large laboratories and thirty smaller ones, the former being for undergraduates and the latter for men engaged in research.

The small laboratories have very little permanent apparatus in them, and are so arranged that any type of equipment may be employed from time to time. Every room has outlets for all types of electric current; and steam, gas, hot and cold water, and compressed air are piped to every room.

The main lecture room is completely equipped, and can be darkened easily and quickly by touching a button. The library is comfortably furnished; it contains two fireplaces which are attractively panelled, and above them are inscribed the following mottoes:

FELIX QVI POTVIT RERVM
COGNOSCERE CAVSAS

"Happy is he who hath learned the whence and wherefore of things" (Vergil, Georgics, II, 490); and

NON EST MORTVVS QVI
SCIENTIAM VIVIFICAVIT

"He is not dead who hath given new life to knowledge." (Quoted by Richard de Bury, Philobiblon, Chap. 19, from Amagest of Ptolemy the Mathematician, who lived about 139 A. D. The original work, in Greek, has been lost.)

At the conference on catalysis and the mechanism of chemical reactions the following papers were read and discussed:

Chemical and Electrical Properties of Adsorbed Films on Tungsten: Dr. Irving Langmuir, of the General Electric Company.

The Mechanism of the Catalytic Oxidation of Ammonia: Professor Max Bodenstein, of the University of Berlin.

Fluorescence and the Problem of Negative Catalysis: Dr. Francis Perrin, of Paris.

Trace Catalysis and Chain Reactions: C. N. Hinshelwood, of Trinity College, Oxford, England.

Atomic Reactions and Luminescence in Highly Dilute Flames: Professor M. Polanyi, of the Kaiser Wilhelm Institut, Berlin.

Parahydrogen, Atomic Hydrogen and the Mechanism of Flame Reactions: Drs. K. F. Bonhoeffer and P. Harteck, of the Kaiser Wilhelm Institut, Berlin.

Finally, Professor Hugh S. Taylor summarized the following communications:

"The Historical Development and Theory of Ammonia Synthesis," by Drs. A. Mittasch and Frankenburger, of the I. G. Laboratories, Oppau, Germany, and "Kinetics and Adsorption at Contact Surfaces," by Drs. H. Mark, Dohse and Kälberer, of the I. G. Laboratories, Ludwigshafen, Germany.

William Foster

THE SCIENTIFIC MONTHLY

DECEMBER, 1929

THE METHOD OF EVOLUTION

By Professor H. J. MULLER

UNIVERSITY OF TEXAS

I. THE "FACT" OF EVOLUTION

DOUBTLESS most of my readers know the story—it is said to be largely fictitious—of Kaspar Hauser. According to this story there appeared one day on the streets of a town in Germany, about a century ago, a youth, half blinded by the light of day, bent and decrepit, practically unclothed, unable to talk, dazed and befuddled by the objects about him and the persons who crowded round. His origin was traced—so the story goes—to the cellar of a house, then abandoned by its owners, where for some unknown reason he had been kept since infancy, without companions, practically without care, his food being thrust in to him and no knowledge or hint of the outer world being allowed to reach him for some sixteen years. When the owners left he escaped, and was dumbfounded to discover the world. But he was not feeble-minded; he learned to talk; he learned the use of objects and the ways of people, and so, undertaking work and forming human associations, he became drawn into what for most men would be the ordinary stresses and cares of life. The tremendous change seems, however, to have overstrained the powers of adjustment of his cramped mind and body, and he lived a short, tragic life, capped by violent death.

This is a fitting allegory for describing the present situation of mankind—at least, the first portion of the story seems *à propos*, although we may hope that the ending will not be. Mankind to-day is in the position of Kaspar Hauser on his first emergence. For ages we have remained cooped up within blank walls of artificial construction, knowing of nothing beyond, behind, beneath, above; imagining at most another cell or two much like our own cell on the other side of the wall. Unexpectedly, however, through a combination of luck and a certain amount of scheming, we have managed to creep through a series of crevasses in the structure, and have gained a view for the first time of the brilliant real world outside. It stretches far beyond our reach, but is ours to roam.

The vastness of the amount of space and material is but one aspect of this sudden expansion of our universe. The seemingly magical extension of matter inwards, discovering microcosmic realm within realm in the interior of all parts of all things, is another direction in which as yet unlimited vistas have opened. But in following our chosen topic we are concerned more with a third kind of removal of bounds, lying in the realization of the tremendous reaches of time behind and before us, as compared with our primitive conceptions of earth and life history, and in the realization of the immensities of change that have occurred, are occurring and will occur in that life, during periods of time such as we have evidence for. It is this which shakes our human composure, perhaps more than any other revelation

of nature. We were not we; they were not they; things are not as they were and will not be as they are. In the bodies and spirits of living things, as well as in their outer environment, transfiguration has gradually followed transfiguration so as to remake them again and again into totally unrecognizable beings. And more than ever are we now in the grip of these transfigurations.

The protracted reaches of time, with their long-drawn-out processes of transformation, now stare us plainly in the face. Go up the steps of the main building of our university and look beneath your feet: the dead relics of fantastic creatures of the sea that crawled here many millions of years ago are obvious everywhere, ground off to serve as your footrests. Follow with the geologist and trace these changes and others grade by grade. Then delve into the history of your own body, as it unfolded its heritage from the egg, and note the dim rehearsal of past events that it seems so unnecessarily to go through, as by some ritual incantation recounted every generation anew: in your early stages *your* gill slits, *your* fish's heart, fish's brain and fish's circulation, then later *your* split lip, *your* pointed ear, *your* coat of body hair, *your* tail. And note the traces of these obsolete structures, in lowlier creatures so useful, even in your adult selves. Now accompany the breeder of plants and animals to his farm, and let him show his new and fancy varieties. Compare them also with the records of their ancestors and, if you can, deny the plasticity of protoplasm.

Is evolution "a fact"? Am I a fact? What is a fact? The philosopher says that he can not say I am a fact, but that he knows *he* is a fact, and that that is all he knows for sure, but I am not sure he knows that much. However, I will not dispute it with him. He and I and evolution may all be a hoax, but I think we have enough evidence to convince us that we will all have to stand or fall as hoaxes together. And that is enough to satisfy me, at the present stage of the game. If I am a hoax, you may be sure then there is no evolution, and if evolution is a hoax you may be sure there is no me, but if either evolution or I exist, then you need not doubt that the other exists too, and by the same token: for it is by the same process of piecing together, interpolating, a kind of continuity in the intervals between the separated but consistent momentary glimpses of us which you get sense evidence of from time to time, that you can reconstruct a convincing concept of each of us, evolution and me. Certainly, if any one could prove that evolution had not occurred, in spite of the overwhelming evidence we have of it, I should have my conception of the consistency of the universe so destroyed that I should see little reason left to credit the truth of my own existence. So remember, if you will, evolution is not a fact—no, not at all—no more a fact than that I exist or that you are reading the words on this page.

It ill befits us, however, to remain wrangling over such abstractions when we stand confronted with the view of a great hitherto unknown world of which we form a part. Admitting, for purposes of living, the reality of this world of ours, we must forthwith bestir ourselves to find out its possibilities and the rules which govern its activities. Even though we may be but as little motes drifting helplessly in its great currents, still we can not keep our self-respect as men without striving to understand its operations, and, if possible, to make at least some little impression upon them. What, then, are the methods of operation of these great evolutionary processes in which all life has been caught?

II. The Quarrel Over the Causative Agent

It is here that the real doubt and divergence of opinion among the so-

called "experts" has been supposed to exist. "Darwinism is dead," it is sometimes parroted, and though Kammerer died tragically by his own hand, the hypothesis of the inheritance of acquired characters which he among others advocated is claimed to have plausibility. Many, if not most, medical men still believe in it, but some philosophers prefer evolution through a kind of inner drive—"orthogenesis"; still others who make themselves heard believe that instead, or in addition, there is a direct influence of the kind of environment upon the kind of variations that occur, with the result that fitter and fitter, or occasionally, less and less fit, organisms are brought into being. To "explain" the fortunate adaptive responsiveness on the part of the organism, the guesses range from an internal, rather short-sighted, cell-intelligence, the "entelleche," to an external, far-visioned perfecting principle.

Amongst the various voices—so our students have to learn from some contemporary texts—there are also to be heard the voices of "neo-Darwinians," who arrive at a finite end by an almost infinite number of steps, or slides, back and forth, of almost zero individual magnitude, the backslides, however, being each time discontinued. And opposed to these, it is often stated, are the voices of different kinds of "mutationists." Some of the latter would have one adapted species change directly into a differently adapted species by just doing so; others would have each more advanced type emerge out of the more primitive type by losing an inhibition. Then, too, there are the voices of those claimants who say that new products arise only by the crossing of preexisting types, followed by the formation of a combination type representing certain elements from each of the old. It is not explained here whether the second species arose by crossing between the first and third or whether the third species arose by crossing between the first and second, or both. Altogether, you see, this is not a process of a species raising itself by its bootstraps—not so crude. Here *A* lifts *B's* bootstraps, and *B* lifts *A's*, onward and upward forever!

After such a maze of opinions, of which these form only a part, the slate is left pretty blank (or rather, evenly scrawled over) for the teacher, the student or the outsider to write in, large, his own personal beliefs. Among these, there is one belief which is especially common. It starts out by stating that every effect has its cause, and a definite effect has a definite cause, and goes on to say that therefore it is only reasonable to suppose that a definite kind of variation, or difference arising between an offspring and its parent, must have been due to some definite condition or quality of stimulus, within or surrounding that parent, whether we can at present trace it or not. A repetition of this condition then would bring forth a similar variation again. In some quarters it is added further that such causation must therefore tend in itself to explain the course of evolution. This in turn would seem to circumvent the necessity of invoking "natural selection" to do more than help out in a secondary and occasional fashion. For, it is often said, it feels "*philosophically unsatisfying*" to believe that all the order and organization of living things could have come about through such a chance process as natural selection admittedly is.

It is evident that a real decision of the questions at issue can be reached only on the basis of real data regarding the nature of those differences which distinguish one generation of individuals from its predecessors, and which they in turn tend to transmit as a heritage to their descendants. That is, we must not remain content to view evolution from afar, but must view close up, as through a microscope, the transitions now occur-

ring out of which the evolutionary story is pieced together. The science which essays this study is "genetics."

III. Genetic Principles Reviewed for the Non-biologist

During the present century genetics, building upon the earlier discoveries of Mendel, has practically solved the problem of the method of inheritance of the differences referred to, once they have arisen. All modern genetic work converges to show that the heritable differences between parent and offspring, between brother and sister, in fact, between any organisms which can be crossed, have their basis in differences in minute self-reproducing bodies called the genes, located in the nucleus of every cell. The genes themselves are too small to be separately visible, but hundreds or thousands of them are linked together into strings, and these strings of genes, together probably with some accessory material, are large enough to be seen through the microscope by the cytologist; they constitute the sausage-shaped bodies called chromosomes. We know that, ordinarily, each individual gene in a string is different from every other gene in the same string, and has its own distinctive rôle to play in the incomparably complicated economy of the cell. Moreover, the genes in different chromosomes are different from one another, except in the case of homologous or twin chromosomes, *i.e.*, the corresponding chromosomes which each cell of an individual received from the father and from the mother of the individual, respectively. To match each chromosome that was derived from your father, every cell of you has in it also a similar chromosome (though not necessarily quite identical) derived from your mother, so that it contains in all two complete sets of chromosomes and hence two complete sets of genes. The proper functioning of the cell during its life depends upon the proper cooperative functioning of its thousands of different genes. One complete set of genes would ordinarily be enough for this, but two sets are provided, so that new combinations of the characteristics of different ancestors may be tried out.

Each given gene in the cell must of course have its own specific chemical composition, differing from gene to gene, though there is no doubt a chemical relationship between all genes. As yet, however, we have no knowledge as to what the chemical composition of any individual gene, or of genes as a group, is. Whatever it is, we can not escape the fact that the different genes, through differing chemical reactions with other substances in the cell, produce by-products which have a very profound influence upon the properties of the protoplasm. And through the combined influences of all the chemical products of the thousands of different genes in a cell, meeting one another in the common protoplasm and then interacting in devious ways to form further products again, the exact form and physical and chemical characteristics of all parts of the cell that contains those genes will be determined, for any given set of outer conditions. Changing conditions external to the cell will of course change the properties of the protoplasm too, but what form and behavior it can and will show for a given set of outer conditions depends primarily upon what genes it has. And since the body of a man or other animal, or a plant, is made up of its cells, and the form and other properties of that body depend upon the properties of these constituent cells—their form, the way they fit together and work—it is evident that, less directly but no less surely than in the case of the individual cells, the characteristics of the whole body depend upon the nature of the genes in the individual cells.

These individual cells of the body have, during the development of the

embryo, been derived from the original fertilized egg cell, through a succession of cell divisions in the course of each of which every chromosome and every gene present in the dividing cell also divided in half, one half of every chromosome and gene then entering one of the two daughter cells and the other half entering the other daughter cell. Between divisions the chromosomes and genes usually had a chance to grow back to their original size. Thus it results that every cell of the body has the same kinds and numbers of chromosomes and genes as the fertilized egg had, and as every other cell in the body has. The original two sets of genes of the fertilized egg—one set received from the sperm of the father, the other similar set derived from what the egg of the mother contained before fertilization—are still both present in every cell of you. But these two sets of genes of the fertilized egg were all, and more, than were needed to result in a complete man. We see, then, that every single cell of you, in the skin, the brain or anywhere else, contains the makings of a complete man or woman, and that you are in this sense wrapped up within yourself many trillion fold. Not each cell may grow up into an entire man, of course, but must remain content to do its specialized share, even though it has a full cargo of genes, because its structure and activities are limited and regulated in various ways through the mutual influences received from the other cells in the body. The various cells of different organs developed differently from one another because, though possessing the same genes, they found themselves in different situations, subject to different influences, from the start. Only the germ-cells, then, may eventually realize anything like their full potentialities.

All this explanation, somewhat off the main theme, may serve to furnish some sort of notion of how the characteristics, in fact the entire substance, of any human or other living being depend upon its genes, acting in a chemically coordinated fashion. So complicated is the manner in which the products of the different genes react with one another that no final product and no characteristic of the adult body is due to any one specific gene, but in the production of every organ, tissue or characteristic, numerous genes take part. Nevertheless, if one individual differs from another individual in regard to just one of the genes that do take part, it will be seen that the given characteristic in the two individuals will be different, and so, conversely, a difference between two individuals in regard to a certain characteristic, let us say eye color, may be due to a difference between just two given genes in them rather than other genes. We may then call these for short the genes "for brown" and "for blue" eyes, respectively, while remembering that really, in both individuals, many other genes are present also which are helping to produce the exact eye colorations seen, but that these other genes happen to be alike in the two individuals in question and therefore are not causing this particular difference, between this brown eye and this blue eye.

By studying the characteristics that appear among the descendants in later generations, after individuals differing in regard to one or more genes have crossed together, the definite Mendelian laws and the laws of linkage governing the inheritance of genes have been determined, and they are found to have a practically universal validity. There is no use attempting here to formulate in detail these rules and their working out; this usually occupies the major portion of a course in genetics. It is sufficient to call attention to a few pertinent facts.

When two germ-cells that differ in respect to a certain gene, *e.g.*, the egg having the gene for brown and the sperm

that for blue eyes, fertilize each other, neither gene is lost, but the resulting individual possesses both genes in every one of his cells, even though his eyes may show preponderantly the brown color, brown being said to be the dominant gene and blue the recessive. Half the germ-cells formed by an individual of such mixed composition ("heterozygous," we call him) will carry the brown gene and not the blue one, the rest carry the blue gene and not the brown, and so there is as good a chance for any one of his children to inherit the blue gene as the brown one. Moreover, it is found that neither the blue gene nor the brown one, when inherited by the next generation, shows any weakening or other trace of its former sojourn with a gene of opposite character. It persists through the generations uncontaminated by its associate-genes.

Now if the individual of dual composition had also been dual (heterozygous) in regard to some other kind of gene, say for hair shape, having received the gene for curly hair from the parent that gave him brown eyes, and the gene for straight hair from the parent that donated to him the gene for blue eyes, then, although he would probably show moderately curly hair, nevertheless, as in the case of the eye colors, half of the germ-cells which he produced would carry curly and the rest would carry straight. However—and here lies the important point—not all those germ-cells of his that carried brown would be the ones carrying curly, nor would all those carrying blue carry straight; there would be some carrying the combination, new perhaps for this family, of brown eyes with straight hair, and other germ-cells carrying the converse new combination—blue eyes with brown hair. Thus, by crossing and recrossing individuals with different genes, new combinations of these genes will be produced in subsequent generations until all possible combinations of the differing genes in crossable individuals have been given a trial. Occasionally totally new effects, new characteristics, are thereby produced, when some new combination is obtained through the unexpected interaction of genes which never before had been tried out together, but such cases are rare. Were the process just described the only method of obtaining change in the characteristics, or combinations of characteristics, of organisms, evolution would soon reach its limit.

On analyzing the results of various crosses, it is found, as might have been expected, that closely related individuals differ in respect to relatively few (though sometimes absolutely many) genes, so-called unrelated individuals of the same race differ in more genes (in fact, in about twice as many as do brothers or sisters), individuals of different races differ in still more genes, and those of different species, where the crosses can be made and analyzed, are found to differ in a yet greater number. In each case, however, the differences are of the same general nature—differences in ordinary genes in the chromosomes, that normally are handed down in heredity in the orthodox Mendelian fashion. In fact, in some cases, as Baur and others have found, the difference between two members of a family may be in regard to the very genes which also distinguish two different species as a whole. The species-differences, then, are simply more abundant, and have had a chance to become more select(ed). And there is every reason to believe that the same is true of the differences between more widely separated groups (with the further proviso, that the number and arrangement of the genes, as well as their kind, may be different). For, in the course of evolution, as one species changed into another and then again into another, it would gradually diverge so far from its progenitors as to be placeable in a separate genus, then in a separate family, order, class, etc., al-

though all along differences would be accruing in the same manner as before. If they can accrue in any other manner we should by this time have gotten evidence of it. But we are running ahead of our story, for the manner of origin of the differences has not yet been considered here.

Most of modern genetics has been occupied with tracing down the above "facts" (if this term may now be used, subject to the qualifications previously expressed). They relate essentially to the method of transmission, to later generations, of gene-differences that are already found to exist between individuals. They show the universality of these differences, their comparative permanence and their recombining capabilities. But they leave untouched what now becomes the major question—how do such differences originate in the first place? What is the origin of variations?

A hitherto rather incidental, yet very important, part of modern genetics has had to do with the problem just raised. It has been discovered definitely that differences between genes do arise, *de novo,* as it were. That is, not all the gene-differences now existing in a population have existed in it from the beginning. New differences are continually arising, somehow, and the differences now existing have undoubtedly arisen in the past in a manner similar to these.

Each gene-difference arises suddenly and full-fledged, though we may not be aware of it at once. Thus, in a population of gray-colored mice, suddenly, in a certain cell of one individual, one of the genes whose cooperation is necessary for the production of the gray color undergoes a change into a gene of different composition that tends, in its interaction with the other (unchanged) genes for color, to produce a yellow tinge instead of a gray. In this single cell, however, the change will not be observed by us. But if this cell, or one of the cells derived from it, happens to be a germ-cell, an offspring-individual may be formed in the next generation all of whose cells carry this new gene. Then if the new gene is dominant (as it happens to be in the case of yellow *versus* gray in mice) to the old gene for gray which the offspring has received from its other parent, the coat of the new animal will be yellow, and we will see that a mutation has occurred. But if the new gene had been recessive, the gray dominant, the offspring would have appeared gray like its parents and we should not yet have been aware of the mutation. The new gene might persist none-the-less, and be inherited by generation after generation in invisible fashion, being meanwhile "dominated over" by the gray from the other parent. If in a later generation two descendants both of which carried the mutated gene happened to mate together, an egg with the yellow might become fertilized by a sperm also carrying yellow, neither, therefore, carrying the dominant gray, and from such a union a visibly yellow offspring would emerge for the first time. A mutation, when recessive, may accordingly fail to manifest itself for many generations, or may never have a chance to show itself at all, before the line of individuals carrying it becomes extinguished. (It has been shown by Fisher that most mutations must meet this mute inglorious fate.)

The new gene, once it has arisen, is ordinarily as stable as the old. The change is definite and fixed, evidently of a chemical nature. Once it has occurred, we have a new mutant gene which will eventually either spread throughout the population or be killed off, according to whether the individuals which carry it reproduce more offspring or fewer.

The effects of mutations are of course as varied as the gene-differences which are found to occur within populations, since these gene-differences originated by

mutation. Some gene-differences, some mutations, produce large and startling effects, like growing a leg on a fly's forehead. Some affect the whole body in practically all its parts, others change two or three characters, others apparently but one. But the less conspicuous changes, the insignificant effects that are easily overlooked, or that even, in many individuals, quite overlap the normal type, seem at least as apt to occur as do the pyrotechnical varieties. Evidence is not lacking that physiological changes, and changes that can only be detected physicochemically, are probably as frequent as changes in visible structures, but geneticists have till now had to have a predominantly morphological training, and anyhow the morphological is easier to see and deal with. It would be absurd and scholastic to try to classify mutations according to the nature of their effects. A mutation can do practically anything that life can do—or at least a little of it, for life is built out of mutations.

IV. The Randomness of Mutations

The statement just made does not necessarily mean, however, that the average mutation does very much in the furthering of life. You will recall that perhaps the biggest question among the older schools of evolutionists was this: Do variations have a tendency to be adaptive, to further life? Is there any evidence in them of an internal or external adapting or perfecting principle, call it what you will? Any kind of inheritance of acquired characters, orthogenesis, direct adaptation of the germ-plasm to environment, or single-stepping origination of species requires this. What do the data on the actual occurrence of mutations show?

They show just the opposite, and in so doing they support Darwin. The vast majority of observed mutations are positively detrimental, and handicap the individual less or more in the struggle for the survival and reproduction. In fact, as Altenburg and I showed in some studies on the fruit-fly, *Drosophila*, in 1919, by far the greater number of detectable mutations in it are actually lethal: their effect is to kill the animal before it becomes adult (though of course their effect may be prevented if they are recessive and if the dominant normal gene has been received by the individual from its other parent). Evidence is accumulating that the same situation probably holds in other forms of life. Now this is just what we should expect, and did expect, on the basis of the theory that a mutation is a chemical change in a gene, occurring at random, as it were—that is, without reference to the effect that would be produced, a-teleologically. Suppose you prod the innards of a watch at random—bring about some alteration in ignorance of the effect it may have. Are you likely to make it a better-running watch? A change, purely accidental in this sense, wrought in any complicated organization is more likely to injure or wreck than to improve that organization for the specific function (in the case of life, multiplication) which it subserves. But, unless the organization has reached its absolute maximum of efficiency already, there will still remain *some* changes, and therefore *some random* changes, that will help. And so, occasionally, when your watch has stopped or is running poorly, you may knock it, prod it, or drop it, and find that, by the lucky replacement of a cog, or the displacement of a sand grain, it starts up merrily again. We shall return to this topic later. Meanwhile, we stand on our data: despite the staggering complexity of adaptation in living things, the vast majority of mutations are, as is to be expected, antiadaptive.

It will not suffice, however, simply to call the changes "accidental." An acci-

dent is something whose cause was independent of something else you are interested in, but every accident has its cause just the same. And so we return again to our perennial question: What is the cause of mutations? Evidently, we may now say, not any outer or inner tendency toward perfection of the life force, but that does not help us very much, scientifically. The mutations whose origination has been known to geneticists have been on the whole very scattered and sporadic, so that little of definite information could be obtained, by collecting these observations, concerning the conditions which may have been contributory to their occurrence. The trouble was that mutations having a conspicuous visible effect are so very rare anyway that one does not find enough in any one experiment to "count." However, the very negativeness of this result, and the varied character of the mutations as they did occur, suggested that their occurrence had little or no relation to the ordinary variables of the environment.

Altenburg and I, in the work previously alluded to, undertook a more systematic test of the possible effectiveness of temperature, by using a technique by which we could count the occurrence of lethal mutations, since we found these arose so much oftener as to be countable, and we obtained results indicating, though not proving, that a rise in temperature caused a slight increase in mutation frequency, even as it hastens chemical reactions. Later evidence seems to substantiate this, but the result at best scarcely goes far enough to afford a workable handle for the study of mutation phenomena, since the numbers obtained even here are so trifling in response to the great expenditure of technical effort necessary. In addition to this work, efforts have been by no means lacking, on the part of numerous investigators, to find the cause, or a cause, of visible mutations, by trying all sorts of maltreatments in the attempt to produce such changes. In the course of this work, animals and plants have been drugged, poisoned, intoxicated, etherized, illuminated, kept in darkness, half-smothered, painted inside and out, whirled round and round, shaken violently, vaccinated, mutilated, educated and treated with everything except affection, from generation to generation. But their genes seemed to remain oblivious, and they could not be distracted into making an obvious mistake in the reproduction of daughter genes just like themselves. The new genes were exact duplicates of the old ones, showing no demonstrable mutations, or at most such a scattering few as might have occurred anyhow.

Either the technique used for finding the mutations was inadequate, or the treatments had little or no effect upon the composition of the genes, or both, and I am inclined to think the latter is correct. And yet mutations certainly do happen, even though rarely. In the examination of over twenty million fruit-flies, not specially maltreated, over four hundred visible mutations have been found. These mutations must have causes. What then can the causes be? What subtle conditions are they, apparently so independent even of violent injury and of other drastic and obvious changes in the physiological or pathological state of the organism? In going over the data on mutational occurrences in *Drosophila* the present writer in 1920 reported the finding of evidence that in this fly, when a mutation occurred in a given gene of a cell, not only did the hundreds or thousands of genes of other kinds in that cell remain unchanged, but even the twin gene of the other set in the same cell—*i.e.*, the originally identical gene that the individual had received from its other parent—remained unchanged also. Here, then, are two genes of identical chemical composition, lying

very close to one another in the same cell —on the average less than a thousandth of a millimeter apart—and one of them is caused to mutate but its duplicate is not. Neither do the identical genes in neighboring cells mutate. Evidence for this same kind of occurrence has been adduced in other organisms. Why do not the same general conditions, acting on the same materials, produce everywhere the same results? If events in this sphere are apparently so indeterministic, is it any wonder that we could not in our previous trials, by the application of definite conditions, produce definite mutational results?

In view of these accumulating findings, the conclusion seemed to me to become increasingly probable, not that mutations were causeless, or expressions of "the natural cussedness of things," or of the devil, but that, as Troland had suggested prior to the finding of this evidence, they were not ordinarily due directly to gross or molar causes, but must be regarded as the results of individual ultramicroscopic accidents—events too far removed from us in fineness to be readily susceptible to any exact control on our part. In other words, an appeal was made to the newly found world of the little to which I alluded in the beginning, and which the old-line biologist and philosopher do not always take sufficiently into consideration.

The genes are not only protected by a cell membrane but by a nuclear membrane inside of that, and possibly again by a chromosomal envelope of some kind; they may be well shielded, therefore, from the reach of any poisonous substances or unusual products of metabolism. They can not, however, escape the interplay of the helter-skelter molecular, atomic and electronic motions that are continually taking place both within and around them, on the part of the substances of which they and their neighbor molecules are naturally composed. Nor can they escape the buffeting action of the electromagnetic stresses and strains occurring through space in the field in which they lie immersed. These various exchanges of energy are not, it is evident, ordinarily consequential enough, or the energy is not directed in sufficiently telling ways, to so distort a gene as to change its composition permanently. Occasionally, however, such a change does occur, and subsequent generations tell the tale.

V. X-Rays a Cause of Mutations

If this general conception of mutation is valid we must regard it as being merely a kind of placing of the problem; we should not yet know just which were ordinarily the critical processes concerned, still less the exact steps involved. The conception carries with it, however, suggestions for further experimental investigation. For among the agents of an ultramicroscopically random character, that can strike willy nilly through living things causing drastic atomic changes here and passing everything by unaltered there—not a ten thousandth of a millimeter away, there stand preeminently the X- or γ-ray and its accomplice, the speeding electron. There is nothing in protoplasm which can effectually stop the passage of X-rays or the related waves of shorter wave-length—gamma and cosmic rays. For the most part, in a cell, the rays will pass through; but at isolated, unpredictable spots, depending upon unknown "chance" details of energy-configurations, a definite portion, a "quantum," of the rays will be held up, and part of the energy thus absorbed will issue forth in a hurtling electron, shot out of the atom that stood in the way of the radiation. The atom will be changed thereby, and hence the molecule in which it lies may undergo a change in its chemical composition. But for every atom thus directly

changed there are thousands of other atoms changed indirectly. For the electron, shot out like a bullet (except far faster), tears its path through thousands of atoms that happen to lie in its way, leaving in its wake a trail of havoc before it is finally stopped. In this process, many of the atoms through which the electron tears have one or more of their own electrons torn out or dislodged from their proper places; this change in the structure of the atoms often causes them to undergo new chemical unions or disunions that in turn alter the composition of the molecules in which the atoms lay. If a gene is a molecule, then, with properties depending upon its chemical composition, it can be shot and altered by the electrons resulting from the absorption of X-rays or rays of shorter wave-length. The only question would be, can enough mutations be caused in this way to be detectable by our present methods, with doses of rays small enough not to kill or sterilize the treated organism?

With these points in mind, the author undertook in the fall of 1926 a series of experiments designed to test the question at issue. The fruit-fly, *Drosophila,* was used, since it is so easily and rapidly bred in large numbers and since it rendered possible the employment of special genetic technique for the finding of mutations, that had been elaborated in the course of my previous work on linkage and mutation in this organism.

It would take us too far afield here to examine this technique in detail. Stocks of flies had been made up containing in given combinations certain genes with conspicuous effects which would serve to notify the investigator that the chromosome under consideration was present. On making given crosses of these stocks with other stocks various combinations of characteristics would be expected in the first and following generations. If flies with some particular expected combination were, however, absent from a given culture, it would mean that a mutation had occurred that had given rise to a lethal gene—one that had killed the flies containing it before they had a chance to hatch. By noting which combinations were missing it could be deduced which chromosome of the fly the lethal was in, and at what place in the chromosome it lay. On the other hand, mutant genes having visible instead of lethal effects would be detectable through the appearance of the visible variations, and these too could be traced to their chromosome position through studies of the nature and frequency of the combinations in which they appeared. Mutant genes that were recessive to the normal type, however, and most mutations are recessive, would not have a chance to be seen or found until the second or third generation of offspring, subsequent to their origination. The reason why recessive mutations are not evident at once has been explained previously.

In these experiments the adult flies—in some cases the males, in other cases the females—were placed in gelatin capsules and subjected to doses of X-rays so strong as to produce partial sterility, though the other functions of the flies are not noticeably disturbed by a dose several times stronger than used here. The treated flies were then bred to untreated mates, and at the same time numerous control matings of the same genetic type were carried on for comparison, consisting of untreated males crossed by untreated females. Thousands of cultures were used in this and subsequent experiments, in order, if possible, to settle the matter beyond any doubt.

The results in these experiments were startling and unequivocal. To the toiling pilgrim after plodding through the long and weary deserts of changelessness, here indeed was the Promised Land of Mutations. All types of mutations,

large and small, ugly and beautiful, burst upon the gaze. Flies with bulging eyes or with flat or dented eyes; flies with white, purple, yellow or brown eyes or with flat or dented eyes; flies curly hair, with ruffled hair, with parted hair, with fine and with coarse hair, and bald flies; flies with swollen antennae, or extra antennae, or legs in place of antennae; flies with broad wings, with narrow wings, with upturned wings, with downturned wings, with outstretched wings, with truncated wings, with split wings, with spotted wings, with bloated wings and with virtually no wings at all. Big flies and little ones, dark ones and light ones, active and sluggish ones, fertile and sterile ones, long-lived and short-lived ones. Flies that preferred to stay on the ground, flies that did not care about the light, flies with a mixture of sex characters, flies that were especially sensitive to warm weather. They were a motley throng. What has been done? The roots of life—the genes—had indeed been struck, and had yielded.

It must not be supposed that all the above types appeared congregated together in one family. The vast majority of the offspring that hatched still appeared quite normal, and it was only by raking through our thousands of cultures that all these types were found. But what a difference from the normal frequency of mutation, which is so painfully low! By checking up with the small numbers of mutants found in the numerous untreated or control cultures, which were bred in parallel, it was found that the heaviest treatment had increased the frequency of mutation about 150 times—that is, an increase of 15,000 per cent.

VI. Similarity of the X-Ray to the Natural Mutations

Yet these mutations were obviously of the same general nature as the spontaneous mutations that occur without X-ray treatment. This was shown by the fact that in many cases changes had been produced which were undoubtedly identical with spontaneous variations which had been found in the previous history of the *Drosophila* work; the effects in these cases appeared identical in every particular, and the method of inheritance, the position of the gene concerned in the chromosome, was found to be the same. In fact, in the chromosome which has been subjected to the most intensive study (the X chromosome), the majority of all the well-known mutations that had previously been found by the dozen or so active investigators in the course of fifteen years now were found to have arisen over again in the cultures of X-rayed flies here. Besides these reappearances there were of course many new types also, more new types than old, but it should be remembered in this connection that new types are continually being found, though with far lesser frequency, in the untreated material also.

The new types of mutations, like the old, conformed in their general expression and mode of inheritance to certain general principles which I have previously observed to hold in the case of the mutations occurring in untreated material. One of these principles was that the great majority of the mutations—of X-ray as well as of natural origin—are recessive to the normal type, despite the presence of a rather small minority of dominants. Thus the technique of breeding out through a number of generations in order to find the mutations was found to be justified. And it may be remarked here that if human beings are affected by X-rays in the same way as flies, we can not expect to find much evidence of a mutational effect of X-rays on them from data derived only from the first, or even the first, second and third human generations, and such a negative result will therefore by no means indicate a lack of significant genetic effect.

The second principle observed was that the X-ray mutations, like the natural ones, included both inconspicuous as well as conspicuous changes, changes of slight or almost imperceptible degree as well as striking changes of structure or quality, and changes that registered their effect, so far as could be determined, only in slight lowerings of the general vitality, as well as those that were more graphically describable. If anything, the more easily overlooked effects were the more frequent.

A third principle noted was that most of the X-ray mutations were in some way detrimental to the animal in living its life—they were steps in the wrong direction in the struggle for existence. This finding has already been discussed in the case of the natural mutations, and it has been explained that this is just what is to be expected, on the whole, of changes that occur at random, accidentally, "by chance"—I care not what term you wish to use to describe the idea that they occur without reference to their consequences, unadaptively, and hence are more likely to be "wrong" than "right" changes, just because there are more wrong roads than right roads to follow, and because, as is well known, the right road is apt to be the narrower. In the case of the X-ray mutations it is easily seen that, if the change occurs as I have pictured it, it *must* occur accidentally, without reference to the possible advantage or disadvantage it would confer, since the shooting electrons let loose by the X-rays are coursing helter-skelter through the cell, quite blindly, and are just as apt to hit one gene as another, to strike it either on its left or its right side, through its heart or its appendix, so to speak, and so will cause one change or another indiscriminately. We have in the X-ray mutations, then, a group of variations which seem *necessarily* to be random, and hence would necessarily be mostly detrimental. In view of this, it is interesting to compare with them in this respect the natural mutations, and to note that, so far as our evidence goes, the natural mutations have, on the average, every bit as much tendency to be detrimental as the X-ray mutations have. The obvious conclusion is that the natural mutations too must be random changes, in the same sense that the X-ray mutations are.

As in the studies on natural mutations, so too among our artificial ones, the great majority were lethal—they killed the fly before it ever hatched, except where there was a normal gene from the other parent to dominate over the lethal and save the fly's life, so that it could be bred and the method of transmission of the lethal studied. The changes in wings, eyes, etc., previously mentioned were only the exceptional visible changes, culled from out of a great mass of lethals. Thus, although the great majority of the descendants of X-rayed flies that lived *looked* normal, many of them carried, hidden by the dominant normal gene, a recessive lethal gene. And if we count up all these lethals we find that the majority of the offspring of heavily X-rayed flies are not really normal in their genes after all, for something over 50 per cent. of them contain some kind of lethal mutation that will not work its destruction until a still later generation. This too deserves being considered in its bearing on X-ray effects in the case of human beings. Now previous studies of Altenburg and myself on natural mutations have shown that among them too, although the total frequency of mutations is so much smaller, nevertheless the number of lethals is just as large, *relatively* to the number of other, visible mutations which occur naturally, as it is among the X-ray mutations. As the lethals differ from the others, after all, merely in being more detrimental, this result simply means again that natural mutations

are just as apt to be very detrimental, *i.e.*, lethal, as are X-ray mutations, thus confirming what I have called the "accidental" character of the natural mutations.

The descendants of the X-rayed flies have been bred through many subsequent generations. It has been found that, where a gene was not caused to mutate in the first place, it will not show a subsequent tendency to mutate, without further treatment, *i.e.*, there is no perceptible after-effect on the genes that escaped an immediate hit. On the other hand, those genes that were hit and mutated now breed true to their new type, which in the great majority of cases gives evidence of being as stable as the original type was before treatment. We now have in the laboratory various mutant races of flies, derived from our earlier X-ray experiments, which have passed through something like fifty or more generations since the time the mutation took place, and there has been no sign in them of any tendency to revert back to the originally normal condition. They have their own, new norm; they are real, new variants. The new forms are permanent, in so far as the word permanent may be applied legitimately to living things. And when crossed to other forms, the new differences obey the same laws of Mendelian and chromosomal inheritance as do the gene-differences existing between natural varieties.

VII. The Nature and Significance of the Genetic Effect of Radiation

It might perhaps be contended in some quarters that while the artificial mutations may be similar in some respects to natural ones, and even identical with some natural ones, yet they may not be similar to those particular natural mutations which may be termed "progressive": the mutant genes resulting from which survive, multiply and thus become a part of the heritage of an evolving species. Such claimants would hold that the X-ray action is necessarily destructive, causing only loss and injury, and that thus it can work *only* harm, or at least can cause no indefinite amount of progress in organization. Such a contention would rest upon a misconception of the action of the X-ray, for it can be shown that the speeding electron is capable of imparting energy to other atoms through which it goes, and that the resulting chemical changes may be of a synthetic character as well as otherwise. However, since we can not analyze chemically the real nature of the changes involved in the production of mutations by X-rays, empirical evidence on the question at issue is called for, and that is what we have been trying to obtain.

It is evident, as my wife has suggested, that if the change induced by X-ray from, say, a gene designated as large A, to a mutant gene of different composition, designated as small a, has really involved a destructive process or a loss, then the opposite change, from small a to large A, must, conversely, involve a constructive process or a gain. With this question in mind, Professor J. T. Patterson and I have been engaged in some extensive irradiation experiments involving particular characters. The character which we have used most is the recessive mutant character termed "forked bristles" (f), as compared with the dominant normal straight bristles (F). The evidence is now positive and convincing that the X-rays not only induce the mutation of straight bristles to the recessive forked, but also the precisely opposite type of change: namely, forked bristles to the dominant straight, and abundant controls have shown that it is really the X-rays which are the inducing agent. Similar but less extensive findings have been made in the case of the mutant character called "scute" and its normal alternative "non-scute." The mutations arising as a result of X-

raying are, therefore, not merely destructive changes, not merely losses. If some are losses, others, then, are gains. Doubtless, as in the case of most chemical reactions, most mutations too are changes involving substitutions and rearrangements rather than mere losses or gains.

It should be mentioned that, in addition to the changes in individual genes which X-rays bring about, they also cause—with considerable frequency, as Altenburg and I have shown—breakages of entire chromosomes or strings of genes, accompanied by reattachments of the broken-off fragments to different chromosomes or to the chromosome-remainder from which they were broken, at a different point from before. The rearrangements of genes thus resulting can be analyzed by breeding tests, and at the same time checked up by studies of the chromosomes as seen through the microscope—an undertaking which Dr. Painter and I have been cooperatively engaged upon during the past two years. In this way we have obtained light on the structure and behavior of the genes and chromosomes from a new angle, though space does not permit me to touch upon these results now.[1] There is evidence that such rearrangements of chromosome parts, as well as mutations in individual genes, have occurred repeatedly during the course of natural evolution.

The question may now be raised: to what extent can all these results be regarded as mere curiosities: effects confined to the mature sperm-cells of the fruit-fly, and of little significance elsewhere? In this connection, it may first be pointed out that my results in producing gene mutations in the fruit-fly were immediately confirmed by Weinstein, working at Columbia University, later by others (Hanson, Patterson, Harris, Oliver) at this laboratory, and more recently by Serebrovsky and his colleagues in Russia and by Dr. and Mrs. Timofeëf-Ressovsky in Berlin. In my own work, the treatments were not confined to sperm-cells, but were also applied to the female, and it was found that both the mature eggs and the immature female germ-cells (oogonia) were susceptible to the mutation effect. Harris has recently extended the finding to the immature germ-cells of the adult male. Patterson has found that the early germ-cells of both male and female larvae are likewise susceptible, and also the larval somatic cells. The latter finding, which has recently been announced also by Timofeëf-Ressovsky, opens up a whole realm of interesting possibilities in the production of mutant areas of the adult body, derived from cells of the treated embryo—such effects as might result, for instance, in an individual with eyes of different colors, or with parts of the same eye different. Casteel has been making an anatomical analysis of these latter effects through microscopic sections of the eye. The production of mutations by X-rays is thus a general effect for *Drosophila*, producible in all kinds of cells in that organism. What, now, of the generality of the effect on other organisms?

I need not, perhaps, remind the general reader of the fact that all the principles of heredity so far discovered in the fruit-fly—the favorite experimental object of many modern geneticists—have proved applicable to animals and plants in general. It is more to the point to mention that investigators elsewhere,

[1] The production of such changes in chromosome structure by means of X-rays has been confirmed by Weinstein and later by Serebrovsky by means of breeding tests on *Drosophila*. By means of cytological analysis, Goodspeed and Olson have found similar effects in tobacco, and so have Blakeslee and his associates in the Jimson-weed. The work of the present author and his colleagues, in studying such changes in *Drosophila* by means of breeding tests and cytological analysis combined, has recently been repeated in an elaborate manner by Dobzhansky, with results that are for the most part in striking agreement with those that had been announced by us.

working on other organisms, have now reported results of the same kind as those now in question. Thus, Stadler, at the University of Missouri, was independently attempting to induce gene-mutations in barley and in corn by means of X-rays and radium at the same time that I was doing my first experiments along these lines on flies, and he has found indubitable evidence of the production of gene-mutations in monocotyledonous plants by both these means. Following my work on flies, Whiting has obtained positive results by the use of X-rays on wasps. Blakeslee, Buchholtz and the others of this group have a mass of interesting mutation results from X-rays and radium applied to the Jimson-weed, Datura, that extended the findings concerning lethal as well as visible mutations to dicotyledonous plants. With these so widely separated bits of the living world sampled and all responding positively,[2] it is a reckless critic who still would cast a doubt as to the probable generality of the phenomenon.

Radium rays, like X-rays, produce mutations, because they too, being short-wave-length high-frequency electromagnetic waves of great energy content, release high-speed electrons, and the cosmic rays, which are still more extreme in these same respects, and so release electrons of still higher speed, must necessarily act likewise. For, as Hanson has shown in experiments with radium, the number of mutations produced depends simply on the number of electrons released and the speed and distance they travel (*i.e.*, on the total energy of ionization) regardless of the source of the electrons. Oliver, too, in experiments with X-rays in our laboratory, has obtained evidence that the number of mutations produced is directly proportional to the dosage of radiation used, and Stadler's work points in the same direction. This being true, there being no evidence of a minimal or "threshold" dosage, we are forced to conclude that the minute amounts of natural radiation present almost everywhere in nature—some of it of terrestrial origin, derived from the radium and other radioactive substances in earth, water and air, and a smaller part of it of cosmic origin, apparently derived from the diffuse and distant factories of matter—all this natural radiation *must* be producing some mutations in the living things on the earth. These mutations must be very scattered and very infrequent in proportion to the total non-mutated population, just because the amount of natural short-wave-length radiation is very small at any one place, but, considering the extent of the earth and the multiplicity of living things, the total number of mutations so produced per year must be very considerable. It can, therefore, scarcely be denied that in this factor we have found at least *one* of the natural causes of mutation, and hence of evolution.

How important is this cause relatively? Is it the sole cause of evolution? We do not yet know. Returning to the investigation of the possible effectiveness

[2] The work of Little and Bagg on mice treated with radium, first announced in 1923, is not referred to in the above list, as the results were inconclusive, probably on account of the very small dosage of X-rays used and the breeding technique employed. Only 2 kinds of "mutations" demonstrated to be separate were found among the descendants of the 12 treated parents, and one of these occurred also among the descendants of the 5 control parents. Both may have been "latent" in the stock before treatment. One of these "mutations" seemed to have numerous and variable effects, dependent perhaps upon various "modifiers" hidden in the original stock. It should be remembered by the reader in evaluating these various changes, in kidneys, feet, etc., some of which have been described separately, that all of them together are equivalent to only one mutation, and that the latter may not have been of recent origin. In a repetition of this work with dosage similar to that originally used, MacDowell and his colleagues have found no evidence of the production of mutations. A stronger treatment, or a more extensive experiment, might well be necessary before the effect could be clearly demonstrated.

of poisons and other influences than X-rays, I have, during the past two years, tried out a number of drastic treatments, using a refined genetic technique similar to that in the X-ray experiments, which would have allowed of the detection of lethals and other mutations with far greater ease, and therefore in greater abundance, than in the inconclusive experiments of the past. Included among the treatments were heavy doses of manganese and of lead salts, which had been claimed by J. W. H. Harrison (on the basis of what appeared to me genetically unconvincing data) to produce visible mutations in butterflies. There was also included a repetition of the experiments recently reported by Morgan, Sturtevant and Bridges, who suspected that they had been able to cause visible mutations in the germ-cells of red-eyed flies by injuring their eyes with a hot needle, an operation which was followed by a release of the optic pigment and its distribution throughout the body.[3] But our trials of all these and various other agencies have given negative results, and it is becoming a question where to stop.

On the other hand, it *seems* to be true that other conditions, internal and perhaps also external, accompanying an X-ray treatment, can somehow affect the sensitivity of the cells to that treatment. Thus Stadler finds that the sprouting cells of seedlings have mutations produced in them in much greater abundance, by a given dose of X-rays, than do the dormant cells of seeds, though some mutations are produced in both.[4] Yet in the case of flies both Hanson and Harris, working independently, find that the genes of growing immature male germ-cells are far less sensitive to the mutating effect of radium or X-rays than are the dormant genes in mature spermatozoa.[4] I find that the genes in the spermatozoa of the adult male are also more sensitive than those in the germ-cells of the female, or than those in the germ-cells of the larval male.[4] There seems to be even more difference in their sensitivity to the gene-rearranging effect of the rays than in their sensitivity to the transmuting effect on individual genes. The activity of metabolism, however, varied by starving, and by feeding and mating the female, had no perceptible influence in my experiments, and, as both Stadler and I have found independently on barley and flies respectively, extremes of heat or cold applied at the time of treatment have little or no effect.

Thus the study of the physiology of mutation-production is opening up, though as yet in a very empirical stage. And meanwhile, X-rays and their relatives remain the only prime cause of mutations yet known. Whether radiation furnishes the exclusive motive power of evolution can eventually be ascertained definitely, through painstaking quantitative determinations of the mutation frequencies existing in the presence of extremely minute amounts of radiation. As stated in some previous publications from our laboratory we have experiments projected which we believe will test this question in flies.

Since, however, mutations in general bear all the earmarks of the X-ray mutations, then, even if not all of them have actually been produced by radiation, it seems legitimate to use the readily obtainable X-ray (radium, etc.) mutations as the handle by which to study them. These X-ray mutations are certainly accidental, being produced by ultramicroscopic events, not individually controllable, that take place without reference to the outcome or the advantage for

[3] They announce that they have recently been elaborating upon this work by similar tests on flies with other eye colors, and by artificial injection of substances derived from the eye.

[4] It is probable that a part, at least, of these apparent differences are due to a relatively lower multiplication rate on the part of most mutated immature germ-cells, as compared with the non-mutated ones.

the organism. The natural mutations—*some* of which we know must be due to radiation—are on the average equally as detrimental, and of the same general nature, so far as their effects are concerned, as the X-ray mutations. Can we then escape the conclusion that they are accidental in the same sense, and that specific mutations are therefore not dictated by any "adaptive reactions" or other specific responses of the organism to climate or to any other features of its mode of life?

Due, then, to the tremendously magnified effect which one tiny gene can produce through the processes of growth and development, we have a molar indeterminism, in the origination of genetic variations, resulting from an ultramicroscopic determinism. (We will not quarrel here about whether or not a Heisenbergian "principle of uncertainty" lies beneath the latter in turn.) But now "natural selection" sets to work, weeding out the many disadvantageous mutants here, allowing the multiplication of a few advantageous mutants there, until again from all the maze of variants we have organization returning, advancing, and so, as a statistical consequence, there results a kind of higher molar determinism, finally governing many features of the actual evolution of the species. Thus we are sometimes furnished with such regular sequences of forms as seen in the gradual modification of the horse's foot, or in the shells of some mollusks, where a knowledge of one part of the series enables us pretty closely to compute the rest.

VIII. The Rôle of Multiplication and of Selection in Turning Accident into Order

It does, at first sight, seem incredible that all the marvelous organizations in the living things about us could have been put together by anything partaking of the nature of accident. But we must remember that it did not fall together all at once, and that it was all made possible by that almost magical property which life owes to the gene—the power of multiplication of mutated individuals.

For many millions of years, blind chemical forces must have acted and interacted in early times to build up ever different and more complicated organic compounds and systems of compounds. A turning-point was reached when from these shifting combinations those self-multiplying yet mutable materials which we call genes happened to become formed. From that time on the different genes, or the little systems of organic matter containing an association of genes, would necessarily enter into a destructive competition for multiplication against each other, until, step by step, through mutation, or the alteration of the gene, and heredity, or the multiplication of the gene, the complicated life of the present day became differentiated.

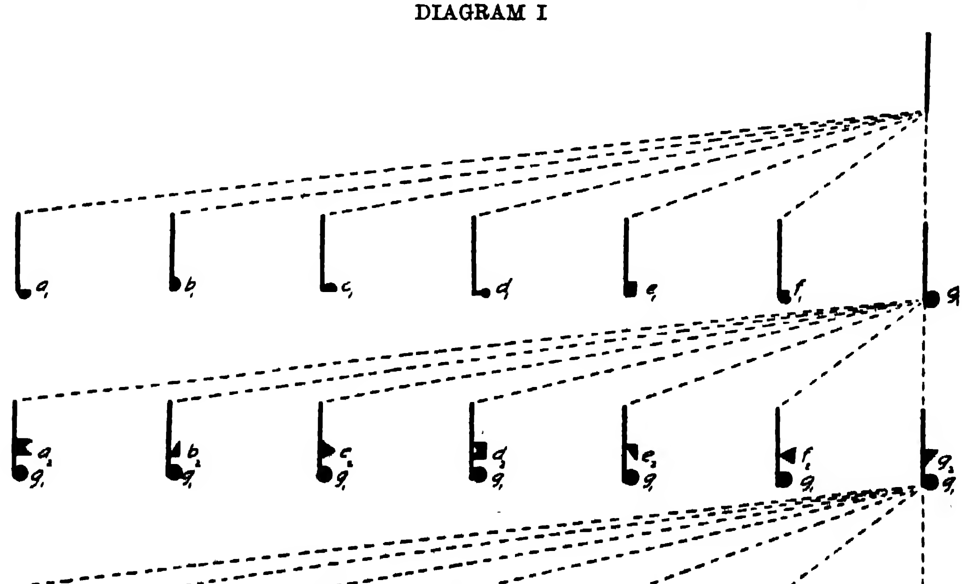
It will be worth our while now to examine more closely just how it is really the peculiar power of multiplication of mutant forms which turns this trick of converting accident into order, by making such very extraordinary combinations of accidents possible as could not otherwise occur. For some reason, this fundamental feature of the matter does not seem to have been fully realized.

In examining the process of evolution, let us be content at first to make our case a very simple one, and to proceed for a while in a very elementary fashion, in order to avoid confusion. Let us first see how just a simple combination of advantageous changes, or mutations, may be obtained in an organism. Suppose we start with some extremely simple organism, represented by the straight vertical line at the top of Diagram I. We will now allow it to reproduce, and allow enough time to elapse so that some mutations or other will have appeared in each of its descendants (they need not be

regarded as first-generation offspring). In our diagram these descendants are shown as vertical lines placed in a horizontal row just below the vertical line representing the ancestral individual, their derivation from which is indicated by dotted connecting lines. We may suppose that multiplication has brought about the existence of seven of these descendants, each with a different "chance" mutation, indicated by a differently shaped spot, and lettered from a_1 to g_1. g_1 may be taken to represent the "good" mutation—the one of an advantageous nature, which is in the path of progress, that happened to occur amongst all the others of a disadvantageous or neutral kind. Now allow a similar length of time to elapse again, in which multiplication and chance mutations take place much as before. The individual with the "good" mutation, g_1, thus multiplies to form seven again, each carrying g_1 (*i.e., the multiplication has involved the variation itself*), but, in addition to g_1, each of the individuals carrying it now carries a second mutation, lettered from a_2 to g_2. Among these second mutations we may again suppose that only one of the seven, g_2, is "good," in the combination in which it occurs. Thus we get a combination, in one individual, of two good mutations, g_1 and g_2, which supposedly have properties that "fit well together," interacting so as to work out advantageously in combination.

Some or all of the other individuals of the previous generation, bearing mutations a_1 to f_1, may also have multiplied. Whether or not they did would not affect our desired result—the attainment of the g_1 g_2 combination—at all, provided only that the g_1 individual itself had been able to multiply and mutate as indicated. If all the individuals of the previous generation had multiplied to just the same extent as the one having g_1 did, there would obviously have been 7×7, or 7^2, or 49, individuals formed bearing some combination of mutations, and of these forty-nine different combinations just one would be the "good" combination—g_1 g_2. Accordingly, with-

DIAGRAM I



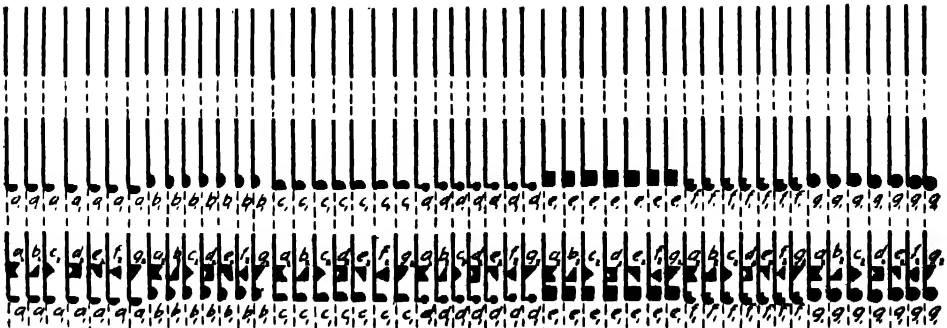
TO ILLUSTRATE THE RÔLE OF MULTIPLICATION IN ALLOWING THE ORIGINATION OF A BENEFICIAL COMBINATION OF VARIATIONS (g_1g_2).

out any "natural selection" or any difference whatever in multiplication rate occurring, there would be one individual in forty-nine having the "good" combination. In still other words, the "chance" of the good combination being present in any particular one of these final individuals, in the absence of natural selection, would have been 1/49. It is to be further observed that, no matter how few or how many of the above forty-nine individuals were actually produced, the ancestors of the g_1 g_2 individual (namely, the g_1-bearing individual and its predecessor, the simple line) had multiplied at the rate required for doing their share in the production of these hypothetical forty-nine individuals.

We may now consider what would happen in the case of some kind of creatures, or objects, which did not have the power of multiplication, but which were otherwise similar to the organisms just discussed, and like them could mutate (or in this case we should simply say, "change"). We may suppose either that these beings produce just one offspring and then themselves die, or that they are potentially immortal and change directly from one form into another. In either case, if their "mutational" possibilities are the same as those of the multiplying organisms previously considered, then we should have to start with seven of them (represented by the seven straight lines at the bottom of Diagram II) to get one having a change equivalent to g_1. But we should have to be provided with seven already bearing g_1 in order to obtain one having g_2 in addition to g_1. Since in the first place only one in seven come to have g_1 (or its equivalent), we should have to start with 7×7, or 7^2, or 49, in order to get the required seven having g_1 (or its equivalent) which would in turn yield the one finally having both g_1 and g_2 (or their equivalents). This is indicated in the diagram. (Here, for convenience in examining the diagram, similar types are grouped together, although chance would scatter them indiscriminately. Also, all forms of "equivalent" type are represented as though identical.)

On comparing these non-multiplying objects with the multiplying ones we then see that, to get a given kind of combination by means of a given incidence of "mutation," we have to start with just as many, in the case of the non-multiplying objects, as, in the case of the others, would have been produced in the end by the entire process of multiplication, if all individuals had multiplied at the rate at which the selected individuals

DIAGRAM II



TO ILLUSTRATE THE MANNER IN WHICH A BENEFICIAL COMBINATION OF VARIATIONS (g_1g_2) MIGHT ARISE IF THERE WERE NO MULTIPLICATION, AND THE NUMBERS WHICH WOULD THEN BE NECESSARY.

did. One out of this total number hence represents the "chance" that our desired combination could have come about purely fortuitously in any particular individual at the end of the given lapse of time, no matter whether the individuals were of the multiplying kind or not. By the laws of chance, if only a few times this total number are given, this combination, or one equivalent to it in "excellence," is practically certain, under the conditions postulated, to be present in one or more individuals.

Organisms, however, represent many more than two advantageous features in combination. By the same reasoning as the above, we may find the chance of obtaining a combination of three features —g_1 g_2 g_3. We may assume again that the g_3 change is in itself, at its time of occurrence, about as rare as either g_1 or g_2 alone was: namely, of the frequency of 1 in 7. It will then be seen that the g_1 g_2 individual must be allowed to go through a period (the third period) of mutation and of multiplication times 7, whereupon g_1 g_2 g_3 will arise. Further, it is evident that the rate of multiplication of the individuals in the line of descent that gave rise to the g_1 g_2 g_3-bearing individual was such as to have given rise to $7 \times 7 \times 7$, or 7^3, or 343 individuals, after this lapse of time, only if all descendants of these ancestors had multiplied at the same rate as they themselves had. In the case of non-multiplying objects, it would have been necessary to *start* with 7^3, or 343 individuals, in order to get a corresponding result—an individual with a rare combination of three advantageous mutually adjusted characters, g_1 g_2 g_3. Generalizing, we may say that if the frequency of an advantageous mutation were 1 in r instead of 1 in 7, and the number of steps involved was s instead of 3, the corresponding total number of individuals would be r^s. All this is, in fact, only a simple application of a well-known and very elementary mathematical principle applying to the formation of random combinations in general.

It is not, however, until we apply this little formula to the natural conditions pertaining to our immediate problem that its full significance for us becomes clear. What shall we take as our "r" (the *rarity* of advantageous, or "organizational" mutations) and what as our "s" (the number of such advantageous mutational *steps*)?

Undoubtedly r changes its value radically at different stages in the evolutionary sequence, but it would seem quite conservative to represent r, in general, as being as small as 100. In other words, it seems likely that at least 100 mutations must usually occur before one occurs of such a special type that it could take part in the improvement of the life-organization. In flies (*Drosophila*) we find that there are something like ten times as many "lethal" and "semi-lethal" as ordinary visible mutations, and even among the "visibles," the vast majority reduce vitality or lessen the chances of survival in one or more ways. It is certain that not 1 in 100 detectable mutations is advantageous in flies; in fact, for all we know, the number may be more like 1 in 100,000.

In the case of s there are almost equally wide limits of uncertainty, but again we may arrive at a safe minimum figure. In flies I have shown that there are at least 1,500 different genes, and probably many times that number. There must then have been at least 1,500 different mutations to produce these genes from their predecessors. This figure, however, seems absurdly small in view of the great complication of a fly's anatomy, physiology and developmental processes. It is very likely, then, that there are many more genes than 1,500 and that each gene has had a history of numerous mutations, which step by step

have differentiated it from one original type of gene. Considering too that man is certainly much more complicated than a fly, we might boldly guess that there may have been a million or more advantageous mutational steps in his ancestry (this would allow, say, 50,000 genes, in each of which, on the average, 20 mutational changes had occurred). Let us first, however, take s, for man, at the undoubtedly far too low minimum value of 1,500, and r at 100.

Our total number, r^s, thus becomes $(100)^{1,500}$. That then is the minimum number of individuals we should have to start with, in the case of non-multiplying objects, to arrive, by "pure chance," at one having the complication and perfection of organization of a man. We shall examine later what the size of this number implies. It is also the minimum number which the multiplication rate of the ancestors of man would have led to, if all the descendants of these ancestors had continued multiplying at this same rate, *i.e.*, without selection.

It might here be inquired whether such a rate of multiplication would have been possible or likely to occur in these ancestors, in the time during which life has existed on the earth. We know that life has been here for a period having an order of magnitude of something like a thousand million years, that is, a million millennia. If there were only 1,500 mutational steps in this time, that would make only one step in each 670,000 years. Our postulate, $r = 100$, requires that an individual in the line of descent of man should multiply at least a hundredfold between each advantageous mutational step that became incorporated in the germ-plasm, and the next one. It is obvious that far more than this much multiplication could easily happen in 670,000 years. For it only takes seven doublings to make a hundredfold multiplication, and the slow-breeding modern European has been able to double his population merely in the space of the last century. The multiplication organisms, then, would have no difficulty in fulfilling these conditions.

Suppose, now, we try the more extreme figures, $r = 10,000$ and $s = 1,000,000$, so that r^s becomes $(10,000)^{1,000,000}$. To go through a million mutational steps in the course of a million millennia would require one mutation to become incorporated in each millennium, or thousand years. It would also be necessary for the selected type of mutant to multiply by 10,000 during this period of time, and meanwhile to undergo another mutation. There can be no reasonable doubt that a millennium is plenty long enough for many another mutation to occur, in all the descendant germ-plasms, but how about the large amount of multiplication here required? Most lower organisms go through a generation in not over a year's time, and are able, when given the opportunity, to multiply many fold in a single generation. If, however, we suppose that the "select" individuals, those with "good" mutations, only increase in numbers, on an average, by 2 per cent. in each generation, then, at a year to a generation, each such individual would increase from unity to nearly two hundred million in the course of a thousand years. This is far beyond our requirement of 10,000 times.[5] Thus we see that the multiplying organism could probably do much better than accumulate 1,000,000 mutations during the time that life has already existed here, even though each mutation represented the selection of the best in 10,000.[6] Multiplication

[5] A 1 per cent. increase, per generation, would give a multiplication of about 14,000 times in a thousand years.

[6] Allowance must, however, be made for the fact that accidental elimination wipes out the great majority of mutant genes within a few generations after their origination. That is, the process of "differential multiplication" or "selection" is very haphazard until a sizeable number of individuals with the mutant gene

hence has probably afforded the opportunity of obtaining an individual that represents a chance of even less than one in $(10{,}000)^{1{,}000{,}000}$.

It should be noticed that, for the evolution of the multiplying organisms, the only two required conditions have been the occurrence of "chance" mutations (which need include only a very minute proportion of "good" ones), and the ability of the individuals carrying these "good" mutations to multiply to an extent which, within the limits of one generation, need be only extremely limited, but which, continued over a great lapse of time by something akin to a geometric progression, because prodigious indeed. In this process the rôle of "natural selection" consists in just this: that by the elimination of the "unfit" individuals, or the restriction of their numbers, room is made to *allow* the multiplication of the others at the rate required to provide the "chance" for the remarkable 1 in $(100)^{1{,}500}$ or 1 in $(10{,}000)^{1{,}000{,}000}$ combination to appear. In other words, selection merely gives opportunity for the multiplication to proceed in the adaptive or better-organized lines at such a rate as would, if uniformly continued throughout, have given the total which automatically contains the "desired" combination.[7]

If we imagine a world in which, through some sort of miraculous intervention, the combinations which we now call the "unfit" are all allowed to persist and reproduce like the others, the evolution of the "fit" would nevertheless proceed much as in our own world, so long as they too were granted the opportunity to multiply as they do here. Thus "natural selection" would not be necessary for their production. But these "fit" or "well-organized" individuals, and lines of individuals, though in absolute numbers as numerous as here, would necessarily form but an infinitesimal fraction of all the unthinkably vast horde of other combinations that had come into existence simultaneously (just as in the hypothetical case of the non-multiplying beings, in which, if we started with this same final number to begin with, we would eventually find included among them by sheer accident creatures as complexly adapted as ourselves). The fact that the fit owed their existence to "chance" would then be obvious, owing to the relative smallness of the minority in which they existed. In our world, the misfits are largely nipped in the bud, and yet, in the sense just explained, we see that we too are really but the vanishingly small, viable, visible fraction of a stupendous ghostly army of potential creatures, involving a total of $(100)^{1{,}500}$ to $(10{,}000)^{1{,}000{,}000}$, or

happens to become established. This is, of course, very much more true in the case of recessive mutants than of dominants, unless there is very much inbreeding. (One effect of this would be to weight the scales of selection heavily in favor of dominants, leaving the recessives as the "abnormal" forms.)

There is another process which works in the opposite direction to the above, *i.e.*, which hastens the "establishment" of advantageous mutations in the selected lines of descent. This process is the formation of new combinations of genes occurring in sexual reproduction. For the sake of simplicity it has been ignored in the above account. By its means it is made possible that various different advantageous mutant genes which have been multiplying simultaneously in parallel, in as many different (but partially overlapping) sections of a population, can be finally combined into one line of descent. Thus many more mutant genes can be accumulated into one (final) line of descent, in a given length of time, than if all the mutational events and selections had to occur successively in a single line. Owing to this factor, the number of mutational steps may well have been of a considerably higher order of magnitude than 1,000,000.

[7] At the same time, we should not minimize the importance of natural selection in determining which individuals will be allowed to multiply, and, therefore, which of the myriads of possible directions evolution will be allowed to take. The old analogy to the process of pruning a tree is very pertinent in this connection.

maybe many more, possible combinations of misfits.

A little consideration may now be given to the size of this theoretical total number, to show that actually it would be quite impossible of physical attainment. Consequently, if there were no selective elimination, multiplication could not possibly have gone on to anything like the required extent in the "good" lines. Likewise, if we had had to do with objects that could not multiply, there could not possibly have been anywhere near enough of them provided in the beginning to allow an organization comparable with that of a higher or even lower organism to be formed in any of them by mere "chance."

Even the admittedly far too low minimum figure, $(100)^{1,500}$, is of staggeringly great dimensions. If there were this many beings actually produced, then, even if each being were as small as an electron, and all the beings were packed tight together, there would not be nearly enough room in the entire Einsteinian universe, packing them in a hundred times beyond the limits of the farthest visible stars and spiral nebulae, for even an insignificant tittle of them. If we allowed each of these packed "creatures" to go through its entire evolution, of 1,500 steps, in the millionth part of a second, and then substituted another "creature" for it and gave the latter a like chance, and so on for a quintillion years, we still should not have begun to make any appreciable impression on the above number. Neither should we if, in addition, each of these packed beings of electron size, present for each instant, were itself expanded into an entire Einsteinian universe, and each of these universes were then crammed with beings of electron size in its turn. In fact, we might continue thus expanding and subdividing worlds time and again without approaching sensibly close to the required figure.

Hence, in beings without the property of multiplication of variations, and its corollary, natural selection, any such incredible combination of accidents as ourselves would have been totally impossible of occurrence within the limits of practically any number of universes. We are thus really justified in feeling that we could not have fallen together by any accident of inanimate nature. But, given the power of multiplication of variations resident in "living" things, due to their genes, and all this is changed, and we are enabled to enjoy the benefits—such as they may be—of being the select of the select, such as it would have taken a surpassingly vast number of worlds to search through, before our match could be found anywhere by the ordinary processes of chance. In that way, I hope, the metaphysician may reach his "philosophical satisfaction" in the contemplation of his own frame and of the processes whereby it came into existence.

IX. The Task Ahead

The biologist is not satisfied to stop there, however. The real problems of the generation of new living things are only commencing to open up. The occurrence of variations, although "accidental" in the sense just explained, nevertheless is subject to a mechanism, our knowledge of which is as yet in its most elementary stage. Moreover, the biologist of broader view is not so well satisfied with his own frame. He knows that there never has been any one objective in the course of evolution, and that every creature, including man, is only on probation, and may give way before another in which a more advantageous succession of mutations happens to come along. The vast majority of species, in fact, have perished along the way, and only a relatively few survive, through change, to form the continuing threads of life that branch out again.

Man, however, is now the first creature in the world to have this advantage—he has reached some understanding of this process of evolution in which he has hitherto been caught and blown about, and with understanding there frequently comes some measure of control. He can now produce mutations for the first time, and I have no doubt he will soon experiment with this knowledge and in time by its means greatly improve and alter the forms and functionings of those domestic animals and plants which he has taken under his care. Look at the motley shapes of flies that have been made in the laboratory, and you may more readily appreciate the possibilities thus presented.

Despite these advantages, we are today almost as far as ever from producing to order the exact mutations which we want. Enough, for the plants and animals, simply to produce a great many mutations and then take our choice, as nature has done in a far slower and more halting fashion. But the research must go on. Man must eventually take his own fate into his own hands, biologically as well as otherwise, and not be content to remain, in his most essential respect, the catspaw of natural forces, to be fashioned, played with and cast aside.

If we have had a billion years of evolution behind us, and have advanced from something like an ameba to something like a man, then, in the many millions of years which are still in store for our world, why may we not be able to make a further great advance, perhaps far greater even than this, because under our own increasingly intelligent guidance? At least, if we are men as we like to think of men, challenging all things, we must make the attempt, and die fighting if need be, with our eyes open.

BRIDGMAN'S NEW VISION OF SCIENCE

By Professor ALBERT P. WEISS
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It is time to inspect critically the exact significance of the claims that the recent developments in subatomic physics will make it necessary to revise the fundamental assumptions underlying science, especially biology, psychology and the social sciences. In the March, 1929, issue of *Harper's Magazine*, Professor P. W. Bridgman reviews some of the recent developments in physics and indicates that Newtonian physics has "presented to the mind a sublime picture of the interrelatedness of all things; all things are subject to law, and the universe is in this respect a unit."[1] This picture he believes must be exchanged for one which shows that "nature is intrinsically and in its elements neither understandable nor subject to law."[2]

When the social scientist or psychologist tallies off the achievements in physics, chemistry, biology, medicine, during the last one hundred years and is then told that this development or evolution is based upon illusion one may wonder whether it is not the physicist who has the illusion. The social sciences are undoubtedly swinging towards the methods of classical physics as supplemented by the recent developments in statistical theory. Before trying to shift to the principles implied in the newer subatomic physics it may be well to scrutinize the behavior of the physicist himself and learn to what extent his discoveries are the product of his own past behavior and the cumulative effects of the social organization of which he is a part.

It may be that the physicist is overestimating his ability as a psychologist. From the standpoint of physical change, law and order do not exist in the external world. Things only happen, either together or one after another. It is the individual who designates the events as orderly or disorderly. The fact that the physicist has excluded from his researches most of the things that are not uniform has blinded him to the fact that this is after all a very irregular universe even in its superatomic manifestations. If there is anything less "understandable" than large-scale social interaction, it remains to be discovered. Compared with international movements the convulsive jerks of electrons are simplicity itself.

The development of natural science in the past was largely a matter of extending the range of the sense organs through microscope, telescope, audion tube, etc. As long as the sensory limit is above that of the cells out of which the sense organs themselves are made, it is possible for the sensorimotor system of the individual to react to some aggregates of electrons and protons (in the environment) through other aggregates of electrons and protons (in the sensitive cells of the eyes).

Now, however, the observational range has reached a degree of magnification where the physicist must use one electron to observe the movements of another electron. The term *observe* actually means to *react to* (a bodily movement of some sort). The simplest recording reaction (pointer reading, verbal or written report, etc.) involves billions of electrons and protons, and it should therefore not surprise us that the home life of an electron is still rather obscure. Experimentally we have the problem of detecting an energy relationship between

[1] P. 443.
[2] P. 444.

two electrons as a function of the energy relationship between billions of atoms (our sensorimotor system). It may be that we have actually reached the experimental limits, but the astounding thing is that we have achieved so much. Instead of saying that "nature is neither understandable nor subject to law" would it not be clearer, although less dramatic, merely to admit that the human mechanism is approaching the experimental limit of discrimination and that no theory has yet been formulated which may be used as an extension or substitute, for the direct experimental reactions of the physicist.

Professor Bridgman supports his thesis of "non-understandability" from an illustration taken from classical mechanics.

> An expert billiard player can, by proper manipulation of the cue ball, make the two balls rebound from the collision as he wishes; this involves the ability to predict how the balls will move after collision from their behavior before collision. We should expect by analogy to be able to do the same thing for a collision between a bullet of radiation and an electron; but the fact is that it never has been done and, if our present theories are correct, in the nature of things never can be done. It is true that. if some one will tell me how the electron bounces away, I can tell, on the basis of the equations given by Compton's theory, how the bullet of radiation bounces away, or conversely; but no one has ever even been able to tell how both will bounce away. Billiards, played with balls like this, even by a player of infinite skill, would degenerate into a game of pure chance.[3]

The very obvious answer to this problem is that under the conditions given, no billiard player at all could be developed. To develop infinite skill in billiard playing the player must be able to *see* all the balls that are involved in the interaction. Suppose he is obliged to play with balls of such a nature that as soon as two balls collide, one of them immediately becomes forever invisible. Certainly such a game is one of pure chance, but it is not billiards. Yet this is just what happens in subatomic physics. An electron can not be illuminated so that it will remain visible throughout its entire path. The source of the illumination is itself a whole series of billiard balls thrown against the particular ball which is used in scoring the game. Under such conditions is there a game of billiards? To conclude further that this demonstrates that there is no uniformity underlying whatever interactions do take place between electrons and light darts is not warranted. Visibility to some physicist is not an essential condition for electron-proton interactions, although visibility is an essential condition for learning to play billiards. The only conclusion warranted by the facts is that one can not play billiards with electrons.

With the formulation of Heisenberg's "Principle of Uncertainty," Bridgman believes that a new note is being introduced into theoretical physics and that this principle is "fraught with the possibility of greater change in mental outlook than was ever packed into an equal number of words."[4] This is a wider mental outlook for the physicists surely, and it signifies that theoretical physics is just beginning to realize the social basis of some of its findings. The science of physics is a social development. It is the product of the interaction among many individuals, and it is not surprising that even its most firmly established principles show traces of a variable factor which is derived from the variability of human behavior.

A curious instance of a type of confusion hardly to be expected from a scientist is encountered in Bridgman's deduction from Heisenberg's principle. The statement of the principle is given as follows:

> Heisenberg's principle states, on the other hand, that the ultimately possible accuracy of our measurements is limited in a curious and

[3] P. 446.

[4] P. 446.

unsuspected way. There is no limit to the accuracy with which we can describe (or measure) any one quality in a physical situation, but if we elect to measure one thing accurately we pay a price in our inability to measure some other thing accurately. . . . The meaning of the fact that it is impossible to measure exactly both the position and velocity of the electron may be paradoxically stated to be that an electron can not have both position and velocity.[5]

Is not the paradox "that an electron can not have both position and velocity" merely a verbal paradox? Electrons move even though the characteristics of their movements can not yet be formulated by some physicist. All that is scientifically justified is the statement that the position and velocity of an electron can not both be measured at the same time. This, however, is only an experimental limitation (perhaps a permanent one) because our present methods of measurement distort one of the variables we are measuring. This occurs very frequently in psychology. If we wish to learn how rapidly an individual can press a key after a sound signal is given, the mere fact that we have measured the so-called reaction time changes the rate of the subsequent reactions. But the psychologist does not conclude from this that a person has *no* reaction time or that measuring the reaction time is "meaningless." He merely reports the conditions under which the reaction times were measured and their degree of variability. In biological, psychological and social measurements the experimental conditions under which the measurements are made often distort the measurements.

Bridgman frequently makes use of the term "meaningless" in a way that is bewildering to a critical reader. To quote directly:

A body has position only in so far as its position can be measured; if its position can not in principle be measured, the concept of position applied to the body is meaningless, or in other words, a position of the body does not exist. Hence if both the position and the velocity of the electron can not in principle be measured, the electron can not have both position and velocity; position and velocity as expressions of properties which an electron can simultaneously have are meaningless.[6]

Instead of saying "a position of the body does not exist" the only scientific statement that is warranted is the one already made, *viz.*, "its position can not in principle be measured." Again there is no justification for affirming that before a body can exist it is necessary for some physicist to formulate its position. The "hence" clause only means that if the measurement of the position of an electron is dependent on light darts it may be forever impossible to formulate its position at some specified instant because the only way we now have of measuring the position of an electron is through the indirect action of light darts on the sensitive structures in the retina of the eye.

There is nothing meaningless about this. It is merely the statement of an experimental limitation. Such limitations are so frequent in the biological and social sciences that they are regarded as a matter of course. However, it does not follow from this that the experimental method must be abandoned. In fact, very few physicists have themselves been influenced by the limitations. There seems to be no marked decrease in physical experimentation, and the experimenters are not relying on any "principle of uncertainty" in preparing their set-ups.

One of the statements which Professor Bridgman makes does represent a change in the point of view of the physicist which is very significant, at least for the psychologist. He states, "The physical properties of the electron are not absolutely inherent in it, but involve the choice of the observer."[7] This introduces an individual and a social com-

[5] P. 446.

[6] P. 446.

[7] P. 446.

ponent into theoretical physics which has been too long ignored. The term physical properties is acquired by the physicist during his lifetime and through his social interactions with other individuals (teachers, colleagues, etc.). The physical properties which are assigned to an electron depend on the physical (anatomical and physiological) properties of the physicist. He can not assign properties that do not act upon his sense organs. This means that one limitation of the physicist's definition of an electron is determined by his own sensorimotor structure and function. In this sense the electron is the verbal invention of some physicist. This symbolism may then be adopted by other physicists.

This brings us into psychology. If the electron is an invention (a verbal formulation of a hypothetical structure of some sort) how did it come to be adopted by other physicists? The psychologist would say that the verbal formulation (symbol) may act as a stimulus for other physicists so as to make it possible for them to continue research behavior which has been hampered because of theoretical limitations. From this standpoint "an electron" is only the name for verbal statements which stimulate physicists to renewed activity within the sphere of their vocation or profession. In the social organization such activity will survive over those stimulating conditions (an inadequate theory) which lead to inaction. In general, research activity produces better conditions for the survival of the members of a social organization. In addition to the biosocial advantages of such an invention, subsequent experimentation may actually lead to a verification of the hypothesis.

The fruitfulness of a purely verbal formulation of a hypothetical principle is well illustrated by the physicist's ether. Most physicists are agreed that the concept of the ether is about one of the most contradictory concepts (from the standpoint of logic) that has ever been formulated. But this did not prevent its use in theoretical physics. If the social character of scientific behavior is recognized then the ether hypothesis was only a verbal stimulus for activity (research in physics) which was hampered without the hypothesis.

Another way in which Bridgman's "choice of the observer" enters into physical theory is through his implicit assumption that a verbal formulation must have a fundamental "reality" back of it. Specifically, do electrons and protons have properties other than those assigned to them by some physicist? If we accept the verbal or social character of the electron hypothesis, of course its elements (the electrons and protons) have only those properties that are assigned to them. However, other physicists may find one man's hypothesis of greater utility by adding to or subtracting from the assigned properties. If the experimental results (Eddington's pointer readings) that are secured with a given hypothesis are nearly identical for all physicists, one way of expressing a high degree of uniformity among the physicists is by classifying the hypothetical properties as "real" properties. However, it should be clear that the term "real" is only a name which indicates the degree of uniformity in the behavior of the physicists (not in the properties of the electrons). It would be clearer, however, not to use the term "real" at all, but merely indicate numerically the averages and deviations of the experimental findings (that is, the pointer readings).

This problem often manifests itself in a more popular form. If the electron and proton are merely verbal formulations (symbols) invented by some physicist, were there any electrons before they were invented? The obvious answer is that since the electron is a verbal inven-

tion, the *invention* did not exist before it was invented. And if it is asked, has the composition of matter changed since electrons and protons were invented, the answer is that it has not. However, the physicist's reactions to matter have changed very much. Some physicists are now reacting to what at one time was called matter in a different way (performing entirely different experiments) than they did fifty years ago. It is the physicists who have changed. The manual and physiological reactions to matter are practically the same as those of individuals living a hundred years ago. It may be that the new responses which the physicists are developing will modify the behavior of all other individuals and it may be that these changes are very significant for survival. To assume an underlying reality having certain absolute properties may be experimentally and technically useful in organizing and classifying human behavior, but such a "reality" is merely a name for specific verbomotor responses that have been acquired by the physicist during his lifetime.

From the psychological standpoint Bridgman's use of the terms, cause, effect, determination, prediction, seems unclear. To quote directly:

> When we say that the future is causally determined by the present we mean that if we are given a complete description of the present the future is completely determined, or in other words, the future is the effect of the present, which is the cause. This causal relation is a bilateral relation; given the cause, the effect is determined, or given the effect, the cause may be deduced. But this means, in the particular case that we have been considering of collision between a bullet of radiation and an electron, that the causal connection does not exist, for if it did the way in which the electron rebounds after the collision would be determined, that is, it could be predicted, in terms of what happens before the collision. Conversely, it is of course impossible to reconstruct from the way in which the electron and the radiation rebound the way in which they were moving before collision.[8]

[8] P. 447.

In this quotation Bridgman seems to say that unless it is possible to formulate what will happen, nothing will happen. It would be more correct to say, if it is impossible to formulate what will happen, prediction is impossible. This is, of course, obvious, because in this case the terms "formulate" and "predict" are synonyms. He is quite right, however, in pointing out that all that is implied by the terms cause and effect is a certain relation between the elements in a temporal series of events. Electron-proton combinations are constantly changing. The change which precedes is arbitrarily given the name of "the cause" and the change which follows is given the name of "the effect." In the widest extension of the use of the terms cause and effect in the modern sense, any one specific event which is occurring now has as its invariable antecedents everything that has ever occurred in the past; and everything which is occurring now is a partial cause of any single event, even the most remote, that will happen in the future. That is to say, the activity that I am now performing in writing this article and the activity of the reader in reading it are partial causes of what will happen on the sun two thousand years from now. The effect may not be of any practical or social significance and it may even elude the finest measurements, but this does not demonstrate that there is no effect.

To give the terms greater specificity science usually limits the term cause to changes such that if they did not occur, the effect would not appear. If the series of changes is of the type that occurs in conformity with a known mathematical equation it is proper to speak of prediction, but such an equation can not be formulated unless a sufficient number of points are established to indicate its geometrical classification as a straight line, parabola, sinusoidal function, etc. After the degree of reliability

has been established either from empirical or hypothetical data it is possible to extrapolate or extend the curve forward or backward. This is all that is meant by prediction. However, this should not be confused with determination. Some events seem to occur in a regular sequence whether or not some physicist is able to formulate the equation which describes this sequence. The uncertainty of electron movements merely demonstrates the fact that no equation which connects the electron and radiation has yet been formulated. It may even be impossible to formulate one on account of the technical difficulties and the limitations of our sense organs, but there is no justification for saying that electrons will continue to act in this apparently helter-skelter fashion until some physicist invents an equation according to which they may henceforth regulate their behavior.

A more concise summary of the baffling character of the principles of subatomic physics is given in the quotation:

> The same situation confronts the physicist everywhere; whenever he penetrates to the atomic or electronic level in his analysis, he finds things acting in a way for which he can assign no cause, for which he never can assign a cause, and for which the concept of cause has no meaning, if Heisenberg's principle is right. This means nothing more nor less than that the law of cause and effect must be given up. The precise reason that the law of cause and effect fails can be paradoxically stated; it is not that the future is not determined in terms of a complete description of the present, but that in the nature of things the present can not be completely described.[9]

As Bridgman here uses the terms cause and effect they imply a practical or social distinction. A cause in the social sense usually means that there are a minimum number of conditions which must be fulfilled before a number of specified conditions will follow. In other words, from the social standpoint the cause and effect relationship usually refers to the problem of environmental control. In biological experimentation, for instance, it is impossible to enumerate and describe *all* the conditions which are the antecedents of some observed effect. However, from a statistical analysis it is possible to determine what antecedent conditions are required before a given galaxy of conditions called the effect will appear. While complete prediction requires a complete description of everything that has preceded, yet for practical prediction the number of antecedents to a limited effect is well within the possibilities of human achievement. The paradox, therefore, that the future is unpredictable because the present can not be completely described, again merely affirms the limitations of the sensorimotor structure and function of man. However, it is this same sensorimotor structure which, through its verbalized reactions, does invent a symbolic set of stimuli through which the movements within the individual may be regarded as a correlational function of everything that has happened, is happening and ever will happen.

Theoretical physics is the product of human interaction, it is not a "reality" beyond human behavior. Professor Bridgman seems to understand these limitations very clearly but when he says that "This inevitableness is rooted in the structure of knowledge" he is introducing a term (knowledge) which can not be said to have achieved a scientific clearness that is at all commensurate with the clearness of such terms as electrons, entropy, relativity, etc. The physicists have not yet learned that the whole question of the nature of the psychological elements and the status of psychological theory is very much a controversial matter at the present time. This uncritical acceptance of psychological conceptions is well brought out in the following quotation:

> The result of all this pondering has been to discover in the principle [that the universe is governed by pure chance] an inevitableness,

[9] P. 443.

which when once understood, is so convincing that we have already almost ceased to kick against the pricks. This inevitableness is rooted in the structure of knowledge.[10]

Professor Bridgman sees very clearly that in the last analysis what goes on in the universe can only be derived from the changes which occur within his own body. In other words, the individual can get into contact with the universe only in so far as his own movements are functions (in the mathematical sense) of movements that have occurred in the external world. Necessarily the degree of functional relationship between my body and the external movements will depend upon how accurately my movements are functions of the external movements, and the degree of accuracy in reacting to external movements is limited by the fineness or coarseness of the structure of my own sense organs. This can be generalized by saying that the individual movements are functions of external movements. Most of the difficulty arises when the physicists uncritically accept such terms as knowledge, mind, consciousness, awareness, as representing entities which are in some way entirely different in structure and function from the processes they are investigating.

This introduces the assumption that there are two universes: one of mind and one of matter. It may be that this is the simplest assumption to make, but at least it should be recognized as an assumption to which there are alternatives. There are many practical considerations which make the assumption of an external world highly probable. The line between the external world of movements and movements within my own body can not be sharply drawn. All bodily movements are muscular movements, that is, contractile effects in muscle fibers. However, these contractile effects are the products of nervous processes or chemical reactions occurring in the nerves which lead to the muscle fibers. These nervous processes in turn are the products of chemical or mechanical processes in the sense organs, and the chemical or mechanical processes in the sense organs are the resultants of movements in the stimuli (of the external world) which act on the sense organ. All this represents a continuum of the type of a differential equation in which the division between one stage and the next is not a sharp line but only approaches a limit. We can not say where external stimulation ends and internal activity begins; we can only approach the limit of the different energy transformations between sense organ, nerve and brain. In the same way further arbitrary distinctions are made between brain and muscle contraction. These may be rather carefully defined as the approach toward some mathematical limit, but they can not be so carefully established empirically or experimentally.

Thus far it has been tacitly assumed that human behavior is a form of motion. For theoretical physics the behavior is the totality of these movements in the various physicists which make up the experiments, records and literature of theoretical physics. Now just where in this series shall the non-physical principles of awareness, mind, knowledge, be introduced? When the physicist speaks of the formulation of his problems as "rooted in the structure of knowledge" he assumes that the psychologist is able to transform the professional movements of the physicist into mental states which have none of the physical properties of the verbal and experimental activities of the physicist. However, there is very little agreement among the psychologists themselves as to what is to be included under such terms as knowledge, consciousness, awareness, etc. In fact, many psychologists have reached the conclusion that it is hopeless to try to give these

[10] P. 448.

terms a scientific status. Such a statement as "the fundamental datum of all knowing is consciousness" sounds reasonable and clear. But this is only due to the fact that such statements have been reiterated so often that there is now no longer a critical analysis of them. Certainly not by the physicists. Scientifically the statement is only a verbal reaction which is a symbol neither for a fact nor for a relationship. It is only a habit of speech that individuals have acquired under certain social (non-scientific) conditions.

When physicists reduce electrons and protons and the interactions between them to conscious mental states they should understand that no one knows what a mental state is, or what the mind is. To insist that it is understood intuitively is simply substituting loose literary habits acquired in early life for the more rigid habits of scientific analysis. It would be a wholesome adventure for those physicists who try to generalize beyond their own researches to try actually to find a definition, description or explanation of mind, awareness, consciousness, meaning, feeling, etc., which they regard as in any sense scientifically clear and satisfactory. As a psychologist the writer should perhaps be ashamed to admit this, but his own efforts at trying to do just this thing have left him no alternative.[11]

The physicists who are now writing on the philosophical or psychological aspects of modern physics are using a psychology which they acquired during their undergraduate years. The psychology of to-day is no more like the psychology of twenty-five years ago than the physics of to-day is like that of the nineties. The physicist may throw up his hands in despair at the confusion which confronts him in psychology, but this does not warrant adding his own even less scientific conception of mind to any of those which he may have rejected. Modern psychology is a closed field for the physicist as such. He may indulge in certain literary speculations and poetic flights, just as any one else may do, but he is no more an authority in the field of human behavior or social organization than any popular writer. More concretely, just what is to be included under the terms "subconsciousness," "instinctive," "experience," in the following quotation?

> The new situation can not be adequately dealt with until long continued familiarity with the new facts produces in our sub consciousness as instinctive a grasp as that which we now have of the familiar relations of every-day experience.[12]

Another example of uncritical analysis is brought out by the statement,

> The physicist thus finds himself in a world from which the bottom has dropped clean out; as he penetrates deeper and deeper it eludes him and fades away by the highly unsportsmanlike device of just becoming meaningless.[13]

That is to say, "meaningless" for the physicist. There can be no sportsmanship at all when one of the players does not know the rules of the game. In this case it is the physicist himself who has not learned how he has acquired the tools (rules) of his own profession.

Bridgman dreads the effect of the new conceptions of physics on the man in the street. To quote directly:

> But doubtless by far the most important effect of this revolution will not be on the scientist, but on the man in the street. The immediate effect will be to let loose a veritable intellectual spree of licentious and debauched thinking.[14]

It is well to point out that the spree is already on and that it is by no means limited to the man in the street. For the

[11] For a more detailed account of the writer's views see his "A Theoretical Basis of Human Behavior," R. G. Adams and Company, Columbus, Ohio, 1929.

[12] P. 449.

[13] P. 450.

[14] P. 451.

psychologist the problem presents a very interesting phase of what happens to the scientist when he is suddenly required to change the habits of a lifetime. The physicists for at least two generations had all their problems nicely labeled and theoretically solved. Something new happened. Roentgen discovered invisible radiations and this started a new line of research. One discovery followed another in rapid succession. Not only was the complacency of the physicists markedly disturbed in their own field but they are insisting that all the other sciences should be equally apprehensive. Surely, they say, if we, the salt of the scientific earth, are so disturbed it is only proper that ordinary persons should go into convulsions. We have lost our bearings, consequently the whole world is about to collapse.

In the biological and social sciences development has been so rapid that these scientists have developed habits which have tended to stabilize their behavior in the presence of profound economic, industrial, political and social changes. This sort of thing is expected and the new developments leave the scientist quite calm and collected and with a realization that he must assimilate the new findings into his old ways of looking at things as rapidly as possible. Sometimes the old way must be completely discarded. He complains about this a bit, depending upon his age, but in the end he does change. Perhaps this is all that is bothering subatomic physics. The change was a little too abrupt for the degree of complacency that the physicists had developed. The last paragraph of Bridgman's article illustrates how completely physics has failed to consider even the most elementary facts of human behavior.

> And in the end, when man has fully partaken of the fruit of the tree of knowledge, there will be this difference between the first Eden and the last, that man will not become as a god, but will remain forever humble.[15]

Bridgman is humble now, and there are a number of other physicists who feel the same way, but this is because they are baffled by the complexity of the physical situation which must be fitted into a social system. Humility is the attitude of the conquered. Man triumphant has never been humble. The marvelous development of industry during the last half century has not developed humility in the business man. Even the physicist will again be proud when certain strained relations between subatomic and superatomic behavior will have been arbitrated.

[15] P. 451.

THE SEARCH FOR MINERAL DEPOSITS

By FRANK EBBUTT
BRITANNIA BEACH, B. C.

No one has, perhaps, realized the importance of minerals to human welfare and to progressive civilization more than modern man. This realization, both on the part of many individuals and by the larger mining companies and interests, leads to a more or less constant though often haphazard search the world over for ore deposits.

The importance of this search for minerals can not be overestimated. Mining is one of the foremost basic industries, and its perpetuation is absolutely dependent on the discovery of new ore reserves. Almost every individual or group engaged or interested in this search for mineral deposits will admit that it is constantly becoming more and more difficult and more costly to find ore bodies of sufficient merit to warrant development.

In the not very distant future the industrial life of America will very largely depend on the ability of the mines to maintain the supply of its many and varied metallic wants. At the present time almost any one at all conversant with the mineral resources of the North American continent, or, for that matter, of the world, can make a fairly accurate forecast as to the life of the known ore reserves for the various minerals. In some cases the predicted life of the known reserves is almost startlingly short, especially when looked at in the light of present consumption and possible or perhaps undoubted increased future needs. On the other hand, no doubt, substitutes for some or even many of the minerals demanded by industry will be found and used by the time the various minerals reach the point where they can no longer be mined at a profit.

Because mining is absolutely dependent on ore finding, ore finding must be recognized as of first importance not only to mining but to all industry, especially manufacturing, which is so dependent on a cheap and unlimited supply of many minerals. Because industry, which spells prosperity and perhaps even civilization, is so dependent on the supply of minerals in their

INDIAN IN SPRUCE BARK CANOE
LIARD RIVER, NORTHEASTERN BRITISH COLUMBIA.

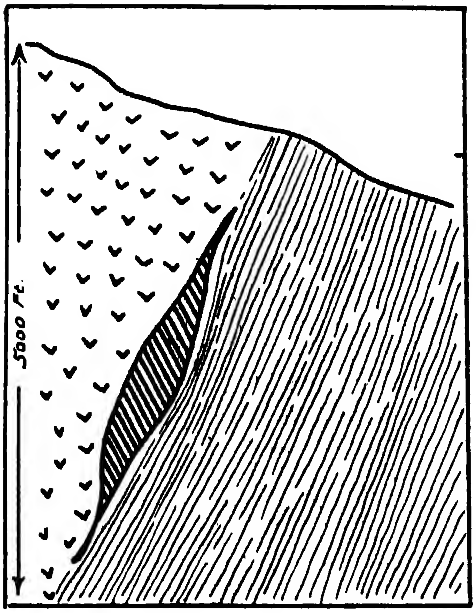


Figure 1.

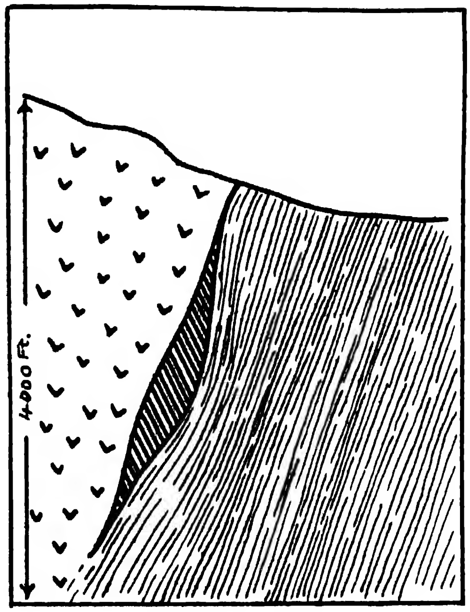


Figure 2.

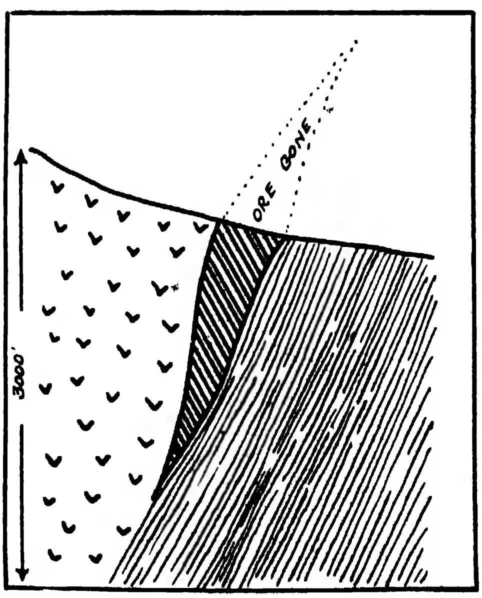


Figure 3.

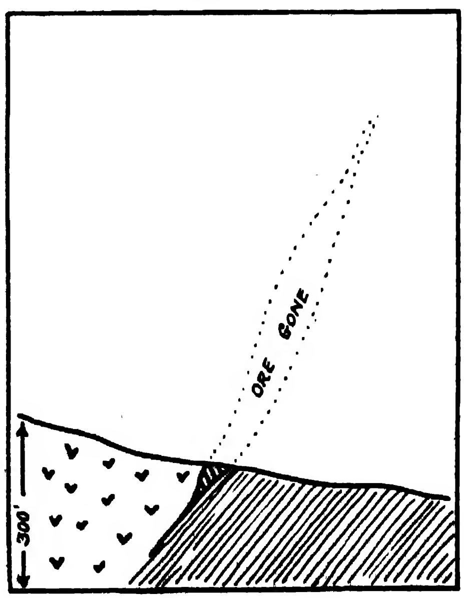
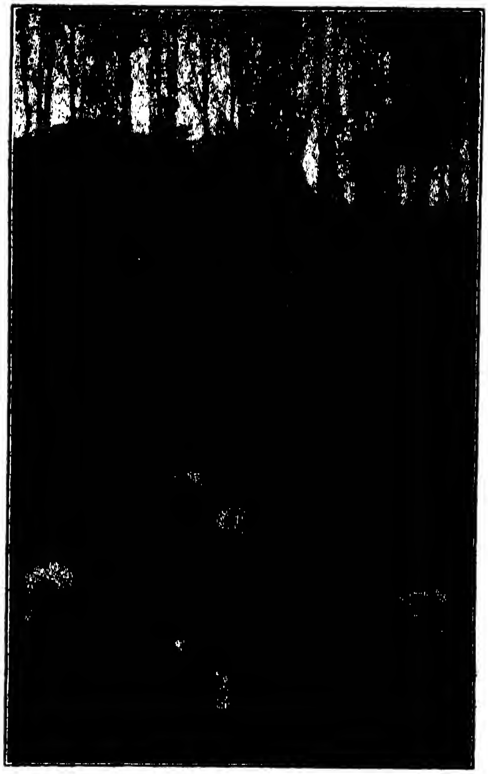


Figure 4.

CROSS SECTION OF ORE BODY

ILLUSTRATING THE SAME ORE BODY AT VARIOUS POSITIONS IN RELATION TO SURFACE, DUE TO EROSION.

raw state, ore-finding methods must be studied more as time goes on, more research must be done along the theories of ore deposition. Much of this work is done to-day, both by the state, by private individuals and by the large mining companies, but all industry will have to realize the need of a future supply and must add its weight to the cause. The U. S. Bureau of Mines, the U. S. Geological Survey, the Canadian Geological Survey and Department of Mines are doing a great work in America. So are many state and provincial departments and surveys—all of which could do much more and better work with larger appropriations. The sums set aside for this work in the very near future must be increased substantially.



PACK TRAIN
PEACE RIVER COUNTRY, ALBERTA.

Most of our big mines of to-day and, for that matter, the great majority of the small ones, were found as the result of the investigation of a noticeable outcrop. In the older districts, where mining has been carried on for several decades, very few discoveries have been made in recent years; some important finds have occurred in Canada in the until recently little known areas. Are we going to abandon districts that have been important producers for lack of outcrops? It must be remembered that few, if any, ore deposits are formed at or even near the surface; they are, in time, exposed by many and various whims of nature's destructive competitor —erosion. This process of nature is a long and tedious one and is far too slow to be any great aid to man in his search for new mineral reserves after he has exploited those which nature took so long to expose for him.

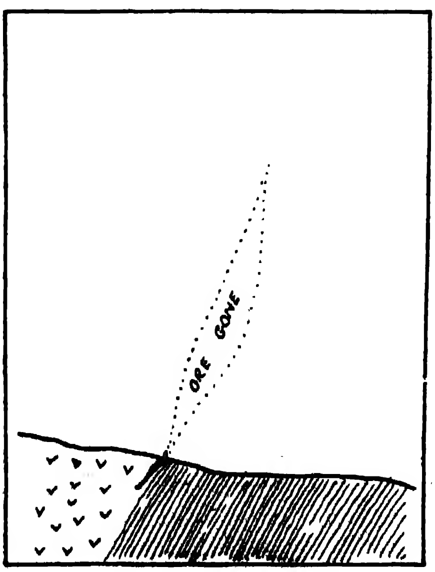
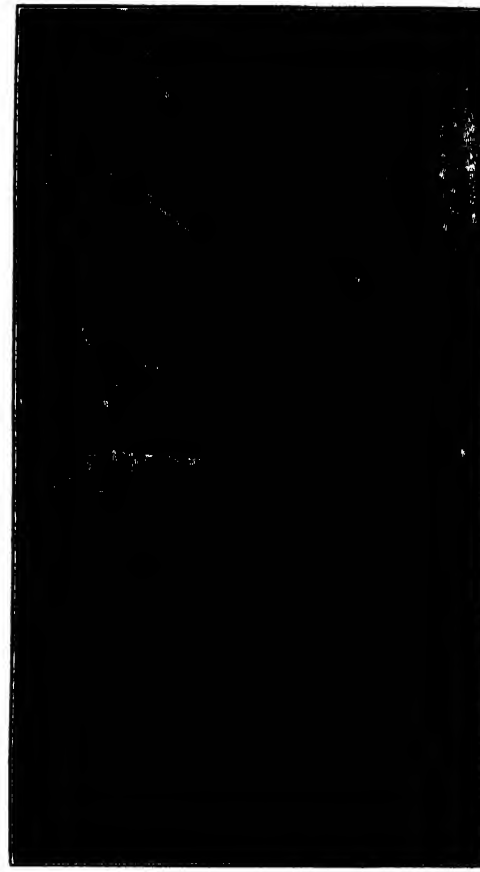


Figure 5.

The several figures will perhaps assist in making the point clear. Fig. 1 depicts section through supposed ore body that does not outcrop—there are no doubt many such instances—truly buried treasure: Such cases as this will be found only after an intensive study and a thorough appreciation of the geology,

which must be based on a very thorough knowledge of the district, its geological literature, past production, etc. Once cases such as Fig. 1 are "sensed," then the various geophysical prospecting methods can be called to the aid of the geologist, for this is his work, not the prospector's. Well-directed diamond drilling should be the next step. Sooner or later finds made roughly along the above lines will be the only discoveries made. There are no "New World" continents with nice noticeable outcrops for man to run to for his future supply of the many necessary minerals; it is evidently a costly process now finding outcrops even in Central Africa.

Fig. 2 depicts an ore body with a poor surface showing, perhaps readily passed up as uninteresting by many. The careful examination by specially trained



BIG TIMBER
West Coast of Vancouver Island, British Columbia.

WINTER IN THE KOOTENAY DISTRICT
British Columbia.

men, blessed with a real appreciation of physiography (which amounts to what the late Sir Archibald Geikie aptly called "Landscape in History"), should lead to the disclosure of the significance of this type of outcrop.

Fig. 3 depicts an ore body with a noticeable surface exposure or perhaps gossan; cases like this are readily discovered by the prospector and quickly developed into a mine and exploited. Such cases are becoming hard to find—some one has stumbled on these before and we have a producing mine or an extinct one in its place.

Fig. 4 depicts a situation which looks encouraging to the uninitiated, the born optimist or the unscrupulous promoter.

Much misdirected capital has been spent on such cases.

Fig. 5 depicts a surface showing that could be, perhaps, mistaken by some for a case like that shown as Fig. 2.

Future prosperity will depend on the skill with which cases 1 and 2 can be found. A small portion of the money spent in the past in an effort to exploit cases like Figs. 4 and 5 would go a long way in the right hands toward the finding of situations similar to Figs. 1 or 2. Cases 4 and 5 must be appreciated and avoided.

In many parts of America the work is greatly complicated, as glacial till, talus slopes, soil and vegetation no doubt mask many deposits in all the various stages or situations.

MOUNT STEWART
SKAGIT RANGE, BRITISH COLUMBIA.
PICTURE TAKEN JULY 5TH.

PTARMIGAN
JUST ABOUT THE BEST DINNER KNOWN.
NORTHERN ALBERTA.

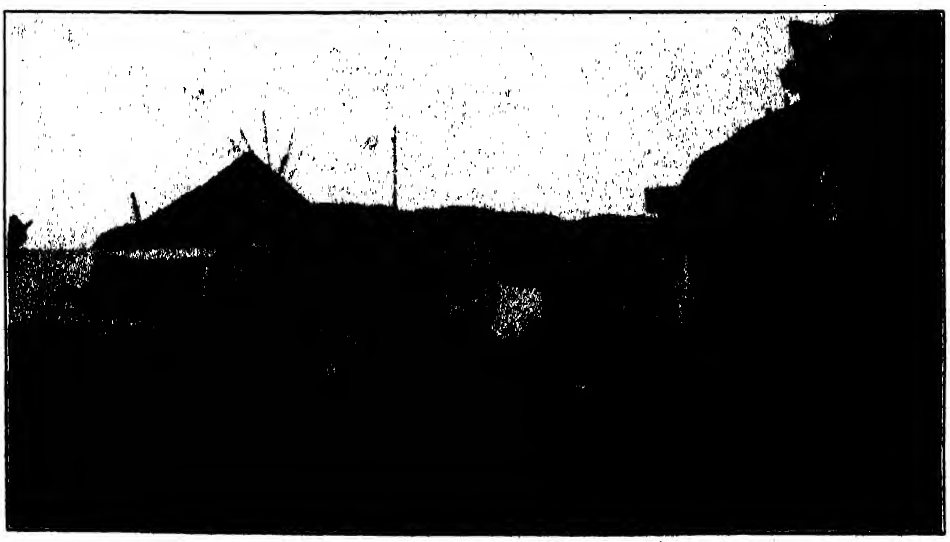
Scouting, as mineral exploration work is usually called, calls for a type of individual not always easily found. The scout must have combined the best of health and an active, robust body with a sound geological and engineering training; he must be capable of facing nature at its best and worst alike. He must quickly adapt himself to any of the various modes of travel, for he will be called upon as a mountaineer, as a river boatman, as a desert traveler, as a dog musher, packer and what not; he should feel at home in an aeroplane. (See snaps by author.) He must be self-reliant, observant and persistent, a born naturalist and a trained scientist. He should have a sound knowledge of mine operating and mining costs; he should be able to drive a good bargain. Admittedly this is a formidable array of pre-

ROCKY MOUNTAIN SHEEP
ALBERTA ROCKIES

requisites. These should serve to make clear the necessity of choosing the right man. Are there going to be enough men of this type to go round? As pointed out in a previous paragraph, not only mining depends on ore finding but an ever-growing industrial civilization depends on the mines for its tremendous metallic needs; this industry is indirectly, but nevertheless very dependent on ore finding.

One nowadays hears a great deal about the reduction of mining costs and the exploitation of lower-grade ore. No doubt costs will be lowered to some extent but there is a limit, and lower-grade ore needs to be in very great quantities if a profitable mining operation is to ensue.

It is common knowledge that more minerals have been used since 1900 than in all previous history. This fact helps one to appreciate the situation and make rough conjectures about the future demand. Can the exploration departments, geologists and prospectors meet that demand? They are going to need help in the form of better knowledge. What is known about ore deposits fills many books, but there are still many



"MAIN STREET," FORT NORMAN, N. W. T.

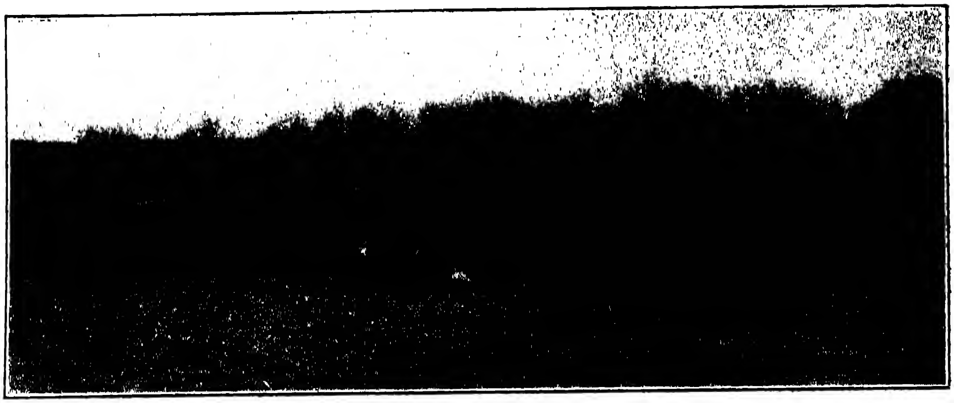
NEAR THE HEADWATERS OF THE McLEOD RIVER
SOUTH BRANCH OF THE ATHABASKA, ALBERTA.

very important questions relative to ore deposition that remain unanswered. There is an urgent need for cooperation; the various national, provincial and state departments and the universities must get together on the subject of ore finding; the fact that the future demand for minerals will be immense must be kept constantly before us.

Gradually, no doubt, conservation of minerals will be practiced and less will be lost by rust and corrosion as these processes are gradually mastered.

We, in America, must remember that

INDIAN WOMAN AND DOGS PACKED
NEAR FORT NORMAN, N. W. T.



RAFTING ACROSS THE BLUEBERRY RIVER
PEACE RIVER DISTRICT, B. C.

what are now our big producing mines and dividend payers will, in time, become exhausted; mining is not like lumbering—there can be no reforestation; mining is not like agriculture—we can not get our mines back by any system of rotation of crops or by the use of fertilizers. Man's hope must rest on the finding of new ore bodies or the invention of substitutes.

GRAVEL RIVER INDIANS
LOCALLY KNOWN AS THE "MOUNTAIN MEN," IN MOOSE-SKIN BOATS ON THE MACKENZIE RIVER, N. W. T.

DO FISHES FALL FROM THE SKY WITH RAIN?

By Dr. E. W. GUDGER

BIBLIOGRAPHER AND ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

Baron Hieronymus Carl Friedrich Munchausen is by unanimous consent nominated the prince of tellers of "big stories," the first president of the "Ananias Club," but he never told of a rain of fishes. Suspecting that he had such a story, I have carefully gone through a number of editions of his book but have found no rain of fishes. So also John Kendrick Bangs found, but, feeling that Munchausen should have told this and a number of other stories, Bangs has written these up under the subhead "Recent Adventures" and published them in a book —"Mr. Munchausen . . . Embellished with Drawings by Peter Newell."[1]

Now it would seem that Mr. Bangs himself also never heard of a veritable rain of fishes, but had to conjure one up out of his imagination. So he resorts to the clumsy expedient of having his narrator-hero when a boy secure a large quantity of gunpowder and plant this in the bottom of a near-by fishpond. When this was touched off the whole pond was blown high in the air and after some days the contents of the pond, including many fishes, rained down on the astonished people of the neighborhood. Peter Newell drew a figure to illustrate this rain, and this is reproduced herein, since it is one of the three known illustrations of rains of fishes printed in books.

Now the interesting thing is that an imagined rain of fishes is not necessary, for there is a multitude of true accounts of such rains. Having a penchant for the unusual in natural history and particularly for those matters wherein fishes are concerned, for many years I collected and filed away accounts of rains of fishes. Thinking that I had gotten together all the reliable narratives of this phenomenon to be found in scientific books and journals, I compiled this mass of data and in 1921 published it in *Natural History*.[2] There were forty-eight of these accounts ranging in time from *circa* A. D. 300 to 1901, and in space from America (eight accounts), Great Britain (ten accounts), Germany (eight rains), France and Greece (one each), through India (ten), Ceylon (three), Malaysia (two) and the South Seas (one).

The publication of the article aroused much interest in this phenomenon, and letters came in calling my attention to overlooked references and giving personal experience. These, together with certain accounts found by myself in the course of bibliographical work on fishes, were brought together in a second article, "More Rain of Fishes," which appeared in *Annals and Magazine of Natural History*[3] early in 1929. In this paper seven new falls were recorded from the United States, a like number from Europe, from Asia and the East Indies four, Australia seven, South Africa and South America one each. These amount to twenty-six, but I think that three are duplicates and that I have established only twenty-three new falls.

There are thus put on record about seventy-one accounts (more or less well authenticated) of rains of fishes, extending from A. D. 300 until the present—a time span of over 1,600 years—and in

[1] Boston, 1901.

[2] 21: 607–619.

[3] Series 10, vol. 3: 1–26, plate and 2 text-figures.

FIG. 1. A RAIN OF FISHES
PRODUCED BY BLOWING UP THE BOTTOM OF A POND, AS ILLUSTRATED BY PETER NEWELL.
From Bangs, 1901.

space, encircling the whole globe. These accounts in range of time and space make for sure testimony as to the actuality of the occurrence of this phenomenon—there could not have been any collusion among authors. I have personally never been so fortunate as to experience or even witness such a rain, but I can not disregard the evidence recorded by scientific men.

There are two figures, other than Peter Newell's given above, of rains of fishes. I discovered one of these on the very day that my first article went to press. It was of such great interest that I published it in *Natural History* in 1922.[4] It is reproduced from a rare old book (so rare that I know of but four copies in the United States), "Prodigiorum ac Ostentorum Chronicon," published at Basle, Switzerland, in 1557. The author was a learned Alsatian named Conrad Wolffhart, who in accordance with the fashion of his times Latinized and Hellenized his name to Conradus Lycosthenes. This picture, which is reproduced herein as Fig. 2, was drawn to illustrate a downpouring of fishes in Saxony in the third year of the reign of Otho, the sixth emperor of that name, the year being A. D. 689, and is found on page 367 of Lycosthenes' (Mr. Wolfheart's) old book.

[4] 22: 84.

Earlier, however, by two years is that shown herein as Fig. 3. It is taken from that stout old story-teller, Olaus Magnus, Archbishop of Upsala and Primate of Suetia and Gothia, being found on page 726 of the first edition of his book, "Historia de Gentibus Septentrionalibus" (Goths, Swedes and Vandals), published at Rome in 1555. Here it forms the head-piece to a chapter entitled, "Concerning the Fall [or Rain] of Fishes, Frogs, Mice, Worms and Stones [from the Clouds]"—surely an all-inclusive heading. However, no statement is made as to when or where these fishes fell.

The good bishop's book went through many editions and in some of these the illustrations were redrawn and somewhat changed. I have looked through the various editions and versions accessible to me in New York, and in that published at Basle, Switzerland, in 1567, I find a variant drawing of the rain of fishes which is reproduced herein as Fig. 4. In this the fishes are falling in three distinct showers instead of two as in the original illustration.

Since the publication of my previous articles there have come to me two accounts of falls of fishes which are so well authenticated that it seems worth

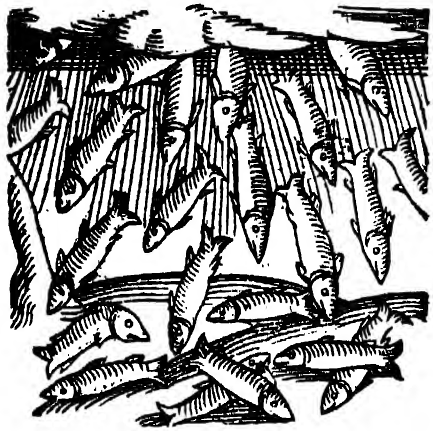


FIG. 2. A RAIN OF FISHES IN GERMANY IN A. D. 689

From Lycosthenes, 1557.

FIG. 3. A DOWNPOUR OF FISHES IN SCANDINAVIA

From Olaus Magnus, 1555.

FIG. 4. A VARIANT DRAWING TO ILLUSTRATE THE RAIN OF FISHES IN SCANDINAVIA

From Olaus Magnus, 1567.

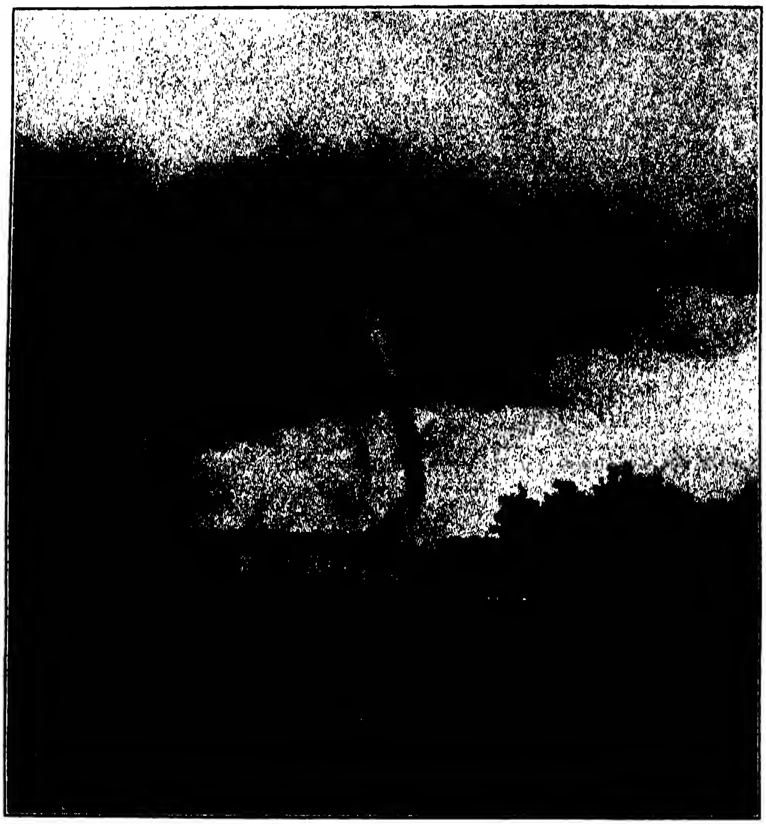


FIG. 5. A WATERSPOUT ON JACKFISH LAKE
NEAR NORTH BATTLEFORD, SASKATCHEWAN, CANADA, JULY 20, 1923. PHOTOGRAPH TAKEN AT A DISTANCE OF ABOUT ONE MILE.
Photograph by courtesy of U. S. Weather Bureau.

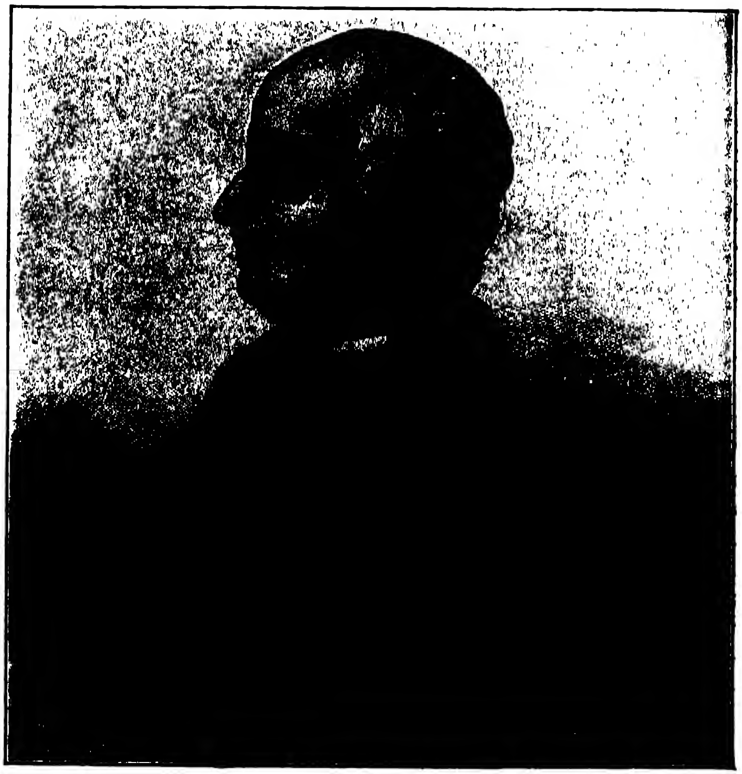
while to put them on record. The first, a personal experience, was related to me by Mr. Richard Hoadley Tingley, of Port Chester, New York, whom I have known personally for a number of years. This fall occurred on May 15, 1900, on the outskirts of Providence, Rhode Island. A severe thunder-storm with a high wind brought a heavy downpour of rain and with it living squirming perch and bull-pouts, from two to four and a half inches long, which fell on yards and streets—covering about a quarter of an acre. Mr. Tingley says that he was out in the storm and was pelted not only with rain-drops but with fish as well. The boys collected these fishes by the pailful and sold them, while a reporter on the Providence *Journal* gathered a bucketful of them and these were displayed in various shop windows on one of the principal business streets of the city.

In July, 1928, I heard of a fall of fishes near Tarboro in my native state of North Carolina. I have spent some time in getting the particulars, and even more effort in getting corroboratory evidence; and I am persuaded that full credence is to be given to the account and to my informants. Here follows the story of this fall of fishes as communicated to me.

On May 18, 1928, a rain of fishes fell on the farm of Mr. S. N. Clark, about

twelves miles east of Tarboro, Edgecombe County, North Carolina. This farm is operated by Mr. W. L. Doughtie, and from him and his wife I have gotten the following details. A heavy downpour of rain came on this day between three and four o'clock in the afternoon. There was very little wind but there were fishes, hundreds of them. These fell on a plot of land that had been planted in cotton a few days before, and which after the storm was covered with water wherein the fishes were found. No one was out in the rain, but immediately after the shower the Doughtie children went out and began wading about in the puddles where they found many litle fishes, some of them alive and swimming. One of the children caught three fishes, brought them to the house and put them in a pan of water. Two of them recovered enough to swim about. Others of the children put some of the fishes in an old unused well, where some of them were seen as late as January, 1929. They were pretty uniform in size, about one and a half to two inches long, about as large as a lead pencil and dark in color. No means were at hand for preserving any of them, hence they can not be identified. Mr. Doughtie estimates that there were several hundreds of these little fishes scattered over two or three acres of ground. This spot is some three quarters of a mile from the nearest water course, which is not known to contain any numbers of fishes.

Now for the explanation of these and all other rains of fishes. There is but one. High winds, particularly whirlwinds, pick up water, fishes and all, and carry them inland where, when the velocity of the air and clouds becomes relatively lowered, the fishes fall to earth. Can any one doubt that a waterspout such as that shown in Fig. 5 could pick up and carry off fishes? In appearance it is just such a one as once passed near me at the Marquesas Atoll about twenty miles west of Key West, Florida. This particular spout on Jackfish Lake, near North Battleford, Saskatchewan, Canada, first appeared from a wheat-field and traveled about fourteen miles down the lake until it was stopped by a small island. Had it lifted from the water and gone inland and then burst, it would have produced a prodigious fall of rain, and had there been any fishes in the lake under its basal end, these would certainly have been sucked up in the whirl, carried inland and later rained down. No reader of this article who has experienced or even seen the prodigious effects and carrying power of a land tornado can have any doubt of the ability of a waterspout, a water tornado, to bring about a "Rain of Fishes."



LAZZARO SPALLANZANI

LAZZARO SPALLANZANI

(1729–1799)

By Professor A. ELIZABETH ADAMS

ZOOLOGY DEPARTMENT, MOUNT HOLYOKE COLLEGE

ALTHOUGH Spallanzani worked nearly two hundred years ago—his birth occurred on January 12, 1729—his findings are still quoted, his methods commended and, especially in experimental science, both the variety and nicety of his experiments and the accuracy of his observations sanction his right to be considered one of the founders of experimental zoology. "The genius of Spallanzani touched and adorned so many things that it is impossible to avoid coming constantly upon his work," writes Cummings,[1] and this statement finds ample proof whether the subject be of zoological import (digestion, respiration, reproduction, spontaneous generation, regeneration and the like), meteorology, the founding of museums of natural history, or travels in southern Europe.

Spallanzani's training[2] was as varied as his interests. After spending his childhood at Scandiano, where he was born, he began his more advanced study at the Jesuit College at Reggio di Modena in 1744 where his principal subjects were law and theology, probably due to the influence of his father who was an advocate. But his later sojourn at the University of Bologna tended to give his natural scientific inclinations free rein, and in this he appears to have been aided and abetted by his cousin, the famous woman scientist, Laura Bassi, and by Vallisneri, professor of natural history at Padua and a native of Scandiano. In 1754 at the age of twenty-five, his appointment as professor of logic, metaphysics and Greek[3] at the college at Reggio is indicative of his versatility, while his first paper, "De lapidibus ab aqua resilientibus dissertatio," is the straw which shows that the wind was blowing in a scientific direction. In 1760, by accepting the chair of physics[4] (some authorities say it was natural history[5]) at Modena, he had the opportunity to give himself more fully to scientific work, and his paper on "The Origin of Springs" was followed by others of a zoological nature on spontaneous generation (Saggio di Osserv. microscop. concern. il systema di Needham e Buffon, 1765), on the circulation (Dell' azione del cuore ne' vasi sanguini; nuovo osservazioni, 1768) and on reproduction (Prodromo di un opera da im primersi sopra le riproduzioni animali, 1768). Sometime in this period he took priest's orders, although it is thought that he was never very active in this profession.

[1] B. Cummings, 1916. "Spallanzani." Sci. Prog. in XXth Cent. Vol. 11, p. 236.

[2] Data for the account of Spallanzani's life are taken from the following sources: Cummings, *loc. cit.;* A. Massaglia, 1925. "Lazzaro Spallanzani." Med. Life. Vol. 32, pp. 149–169; W. Stirling, 1902. "Some Apostles of Physiology." London. pp. 60–64; Encyclopaedia Britannica, 1911. 11th ed. *s. v.* Spallanzani.

[3] Subjects are variously given by different authorities, *e.g.*, Encycl. Brit., logic, metaphysics and Greek; Cummings, logic and geometry; Massaglia, mathematics and physics at University of Reggio Emilia, and Greek and French at the college; Stirling, logic, mathematics and Greek.

[4] At this time he is said to have received calls from Coimbra, St. Petersburg, Parma and Modena; Massaglia, *loc. cit.*, p. 33.

[5] Stirling, *loc. cit.*, p. 61; M. Foster, 1901. "Lectures on the History of Physiology." Cambridge. p. 212.

In 1769 he was called to the chair of natural history in the University of Pavia, and initiated his labors with a defense of the preformation theory. Here he continued his studies on the circulation (De' fenomeni della circolazione osservata nel giro universale de' vasi; de' fenomeni della circolazione languente; de' moti del sangue independent; dall' azione del cuore, e del pulsar delle arterie. Dissertazioni quattro, 1773) and published tracts on spontaneous generation, on regeneration, on mating habits of animals and many other matters (Opuscoli di fisica animale e vegetabile, aggiuntevi alcune lettere relative ad essi opuscoli dal Signor Bonnet e da altri scritte all' autore, 1776). One of the outstanding events of his connection with Pavia was the founding of the Natural History Museum, which he built up largely through his own zeal and ability as a collector. As he later claimed, "It had been born under his hands, it had grown under his direction, and owed its prosperity to his correspondence, activity and travels."[6]

The year 1785 saw him receive an invitation to Padua which he did not accept but used as a tool for securing a larger salary at Pavia and for getting permission and funds for a journey to Turkey, where he was received by the sultan. During his absence from Pavia some of his colleagues began checking up on the specimens in the museum and finding some catalogued but absent from the shelves and being spurred on by jealousy of his popularity in the university and with royalty, they investigated a private museum which he maintained in Scandiano. There they found certain objects labeled with tags of the museum at Pavia and accused him of filching these from the museum. He stood trial on his return from Turkey and was able to clear himself and rout his enemies, some of whom suffered decidedly from having tampered with his affairs.

The later years of his life were spent largely in teaching, investigating and traveling, in publishing other editions of his work on the "Natural History of Animals and Vegetables" and in writing a six-volume account of his journeys (Viaggi alle due Sicile e in alcune parti dell' Apennino dell' abate L. Spallanzani, 1792–1797). His death from apoplexy occurred in Pavia in 1799.

Of what sort was this man, the bare outline of whose life has been sketched above? And why have his labors stood the test of time? That Spallanzani possessed a vivid personality and an abundance of self-assurance seems evident from the impression he made on contemporaries and from all accounts of his contacts with his fellow men. As Cummings pictures him we see a magnetic and assertive man who was bent on having his say in all matters that concerned him.

> Greedy, ambitious, arrogant, and at times violent, Spallanzani was a bull-moose type of man who charged through life with his head down. There were many obstacles to his success, but he brushed them aside; he had many detractors, but he pinned them down. To his opponents in biological controversy he never expressed any flabby desire to agree to differ. They were attacked with acerbity, and whether right or wrong he emerged triumphant. False modesty was not one of the Abbé's faults. When as a young man conscious of his own genius, he ventured upon a criticism of the illustrious Buffon, he did so with a sardonic expression of his own incompetence. He never showed the smallest inclination to mislead his contemporaries into giving him less than his deserts. He set out to be second to none—not even in salary—and he succeeded and was proud of it.[7]

As a critic Spallanzani could be scathing. Nowhere is this more apparent than in his evaluation of Buffon's work on spontaneous generation in the light of his own accurate experimental evi-

[6] Cummings, *loc. cit.*, p. 242.

[7] Cummings, *loc. cit.*, p. 236.

dence. "M. de Buffon's theory is thus completely destroyed. Such is too often the fate of the hypotheses of ardent and fanciful philosophers, first invented and then sought for in nature."[8] And his friend Bonnet even thinks it worth while to advise him of the proper character of scientific criticism. "The examination of Mr. Needham's hypothesis on generation will require a severe criticism from you; but you will make it in polite, moderate, and friendly terms. You are acquainted with the character of this learned naturalist, and cherish the same esteem for him as I do myself."[9]

Together with fanciful hypotheses, garnished accounts of facts well able to stand alone receive a merited rebuke.

> Mr. Brydone, indeed, through his whole journey to Etna has sufficiently shown his attention to the marvellous, and, when that has failed him, has had recourse to the aid of his playful fancy to furnish him with extravagant though ingenious, inventions of the ridiculous kind. . . . But would it not have been more commendable to have furnished his readers with real information, instead of filling so many pages with these trivial and insipid pleasantries? In fact, after having read his five letters on Etna, what idea do they enable us to form of the nature of this mountain?[10]

Then perhaps feeling that he has failed to give proper credit, he adds:

> I do not mean, by what I have said, indiscriminately to condemn the whole work of Mr. Brydone. His "Tour" [through Sicily] frequently contains facts and observations well-deserving attention. It is elegantly written, and the author was well acquainted with the secret of exciting our curiosity, and rendering his narrative interesting; though frequently, with that kind of interest which seems more suitable to romance than to authentic history.[10]

[8] L. Spallanzani, "Tracts on the Natural History of Animals and Vegetables." (Transl. fr. orig. Ital. by J. G. Dalyell, Esq. [2nd ed.] 2 vol. Edinburgh. 1803); Vol. 2, p. 22.

[9] Dalyell, Transl. 1803. Letter from Bonnet to Spallanzani, included in Transl. of Tracts, etc., Vol. I. p. 158.

[10] L. Spallanzani, "Travels in the Two Sicilies, and Some Parts of the Apennines." (Transl. from orig. Ital. of Spallanzani. 4 vol. London 1798); Vol. 1, footnote, pp. 203–204.

Perhaps one of the most attractive glimpses of Spallanzani lies in his own appreciation of his friend Bonnet, the man who with Trembley, Réaumur and Spallanzani was responsible for much of the experimental zoology of the eighteenth century. After describing Bonnet's urgent request to other naturalists to take up and further the experiments on regeneration in earthworms and in higher forms, he says:

> Is there any one who would not wish to obey such an invitation, coming from a man universally allowed to be one of the foremost naturalists of the age? But how much more powerfully must I have been influenced by it, who, besides these invitations in common with other philosophers, was frequently and particularly solicited by him on this account, and who am also connected with him by the strictest friendship, which constitutes one of the chief blessings of my life.[11]

That Bonnet reciprocated that friendship and respected Spallanzani's work, even to crediting him with "discovering more truths in five or six years than all the academies in half a century,"[12] is evident again and again in the former's letters:

> I can not terminate this long epistle, my worthy correspondent, without renewing the testimony of the great esteem, and sincere attachment, which have been borne towards you by the Palingenisist.[13] . . . Fear not that M. de Buffon's authority will in the least invalidate the truth of your discoveries on seminal vermiculi. You have proved yourself an excellent observer, and acquired the right of being believed. You have cherished no theory, but are satisfied with interrogating nature, and giving the public a faithful account of her responses. Philosophers will always listen to you; and they will esteem your observations so much the more certain that you prove yourself to possess the art of observation.[14]

It is not surprising to find that Spallanzani was successful as a teacher. He

[11] Spallanzani, 1769. "An Essay on Animal Reproduction." (Transl. from Ital. by M. Maty. London.) Introd., pp. 3, 4.

[12] Cummings, *loc. cit.*, p. 239.

[13] Dalyell, *loc. cit.*, letter from Bonnet to Spallanzani. p. 266.

[14] *Ib.*, p. 326.

not only had an excellent background of general and of scientific knowledge, but was always eager to try something new, to demonstrate his experiments before his students, to give them the benefit of his philosophical meditations. He could not be content with repeating the minutiae of dry detail which appeared to be the meat of those systematists whom he sarcastically termed "nomenclature naturalists," and only consented to give up his cherished desire to have students use his translation of Bonnet's "La Contemplation de la Nature" for their reference book and to give proper attention to the subject of nomenclature when he was promised an increase in salary. Even then it is said that he managed to intersperse his experiments in the midst of systematics. In addition, he possessed great ability as a lecturer. "Une éloquence simple et vive animait ses discours; la pureté et l'élégance de son élocution seduisaient ceux qui l'entendaient."[15] It is probable that his unwillingness to conform wholly to conventional standards, his enthusiasm as a teacher and his vigorous scholarship all contributed to that popularity which led to his election by the students as rector of the university in 1778, and to his overwhelming reception by them on his return from Turkey and Vienna in 1786.

The second question, why Spallanzani's labors have stood the test of time, may perhaps find a partial answer in the fundamental nature of the questions which he investigated, in the methods he used and in the way he recorded his observations. As already evident in his criticism of Mr. Brydone's fanciful writings, he had no patience with such a style, especially when truth itself was so much more wonderful than fancy. His ideal for scientific papers is given in the introduction to his "Prodromo di un opera sopra le riproduzioni animali," that work which was to have been merely the outline of a much larger work on the same subject.

> To lay down facts with the faithfulness of a true historian of nature; to pass, as much as possible, from the most simple to the most complicated; to bring them together, to analyze and compare them both with themselves and with the discoveries of other authors; to deduce with impartiality the immediate consequences, either favorable or contrary to the explanations given of those extraordinary phenomena; to shew how far the limits of animal physiology are extended by, and what utility and advantage may be derived from observations of this kind will be the principal design of this work. . . .
>
> As several of the results of my experiments will appear singular, I shall make it my business to describe them with precision, to mention the precautions and means I have used in making these observations, the temperature of the air, and the situation proper for the animals, together with the food I gave them; and in short, to disclose all the circumstances which may contribute to the understanding, and establishing of the facts, so, that the lovers of natural history, on repeating my experiments, may, if they please, confirm and extend them still farther. . . .
>
> I have thought a sufficient number of figures would be of the greatest importance to the subject: if they are generally ornaments in books of natural history, they may be said to be the life and spirit of mine.[16]

After reading these quotations it is self-evident why Minot one hundred and fifty years later in writing of the "Method of Science," particularly as it concerns scientific papers, says that "Spallanzani established the modern standard."[17]

Nor when we look over the contents of this work, whose introduction has been quoted in part, and find studies of regeneration in earthworms, in aquatic boatworms, of the tadpole's tail, of tails, legs and jaws in aquatic salamanders, of legs of frogs and young toads, of the head and other parts of the land snail,

[15] Cummings, *loc. cit.*, p. 239. Quoted from Sénébier.

[16] Spallanzani, "Essay," transl. by Maty, *loc. cit.*, pp. 4, 5, 6.

[17] C. S. Minot, 1911. "The Method of Science." *Sci.* N. S. vol. 33, p. 128.

of horns in the slug, all examined from many points of view (*e.g.*, the rate of regeneration, the order of regeneration, the effect of amount removed and age on regeneration, the variation in the capacity of species to regenerate, the microscopic appearance of the regenerating parts, does Garrison's evaluation of the work seem extravagant: "These experiments were not taken up again until the end of the nineteenth century, but they contain all the essentials of the modern work of Roux, Driesch, Morgan, Loeb, and others."[18]

One example of Spallanzani's method of analysis is worth consideration because of the grasp of detail and the thoughtful planning of experiments which it reveals. After noting the necessity of knowing the conditions of the animal before and at the time of the operation, he sets a series of questions as to the results of cutting of earthworms transversely into four, five, six or more parts.

> With regard to the consequences of the section, I examined 1. What new order and disposition the dividing fibers and vessels acquire? 2. What time it takes up after the section, before a new production begins to make its appearance? 3. What is the form and structure of the reproductions; and in consequence, how far they agree or disagree with the first parts? 4. Whether the circulation in the great artery, formed by the reproduction, is analogous to that of the whole worm: namely from tail to head? 5. In what manner are the great artery, the intestinal tube, and the other parts existing in the old animal, united to the new parts? 6. Whether, *caeteris paribus*, the reproduction grows in proportion to the length of time, and the warmth of the weather? 7. Whether all the parts, similar or dissimilar, which existed in the old, are also found in the new, worm? 8. Whether the reproduction, after sections parallel to the plane of the rings, keeps the longitudinal direction of the worm? 9. Whether this direction varies with that of the plane of the section? 10. What interval of time is required before the new-produced parts are able perfectly to perform the functions of those that were cut off? 11. Whether on the lengthening of the reproduction, the trunk increases likewise? 12. Whether after a certain time the reproduction becomes equal to the old part, both in bulk and length?[19]

For studies other than those on regeneration, his enthusiastic persistence succeeded when the efforts of others went unrewarded, and in 1771 he was able to announce the discovery of the circulation of the blood in capillaries in warm-blooded animals. This was exactly one hundred and ten years after Malpighi had demonstrated its occurrence in cold-blooded forms, and after Malpighi himself, Leeuwenhoek, Cooper and Haller had all failed in their attempts to demonstrate the phenomenon in warm-blooded types. As Luciani quotes him:

> Long have I been burning with curiosity to discover the circulation in warm-blooded animals, and to grasp it as completely as in the case of the cold-blooded; hence these vessels ("umbilicals of the chick") attracted my observation more than any others, and invited my consideration, because they belonged to the said animals. Since the room in which I found myself was insufficiently lighted, and I was determined at all costs to satisfy my curiosity, I decided to examine the egg in the open, under direct sunlight. After fixing it in the apparatus of Lyonet ("a small microscope used by Spallanzani") I turned the lens upon it, and, notwithstanding the strong light that surrounded me, was enabled by focussing my eyes, to see plainly how the blood flowed in the entire circuit of the arterial and venous umbilical vessels. Thrilled with this unexpected joy, I felt that I, too, might exclaim, "I have found it! I have found it!" I made this discovery in May 1771, and employed myself in the summer vacation of that year with its development.[20]

Although this discovery and the explanation of the phenomenon of the arterial pulse are perhaps the most interesting that he made in the field of circulation, they are only two of many lines worked upon, such as the elasticity

[18] F. H. Garrison, 1921. "History of Medicine," 3rd ed. W. B. Saunders Co. p. 330.

[19] Spallanzani, "Essay," transl. by Maty, *loc. cit.*, p. 14.

[20] L. Luciani, 1911. "Human Physiology." (Transl.) Macmillan. Vol. 1, pp. 172–173.

of red blood corpuscles, the functions of the heart and the rate of flow of blood through the blood vessels.

Among Spallanzani's investigations which are most often met in the literature are those on digestion[21] and with good reason. These followed the classic experiments of Réaumur and were to some extent repetitions of Réaumur's on digestion in the kite and other animals. The thoroughness with which Spallanzani carried out his studies not only on types of vertebrates from fish through mammals, but even on himself, is indicative both of his method and his analytical approach to the subject. He demonstrated the contractions of the stomach when distended with food, by making a guinea-fowl swallow hazelnuts and then watching the behavior of the stomach as it became filled by the nuts. He studied the effects of the stomach juices on bits of food contained in small metal or wooden tubes or in linen bags, securing them again for examination either by pulling them from the stomach by strings attached to them, in the feces, or by opening the stomach after the objects had been retained a certain amount of time. He likewise procured samples of gastric juice by recovering sponges from the stomach of various animals or by making himself vomit on an empty stomach and used these juices to carry on experiments in digestion outside the body, carefully regulating the temperature conditions and using bits of food in water as controls. By these and many other tests he was able to demonstrate that the gastric juice possessed distinct solvent properties and prevented putrefaction. It is curious that he missed the acid nature of the gastric juice, for some of his experiments seem to demonstrate this so adequately.

[21] Foster, *loc. cit.*, pp. 212–219; Luciani, 1913, *loc. cit.*, Vol. 2, pp. 153, 179, 185, 189; Stirling, *loc. cit.*, pp. 61–62; Spallanzani, "Dissertations Relative to the Natural History of Animals and Vegetables." (Transl. by Thomas Beddoes. 2 Vol.) 1789.

Spallanzani likewise became much interested in the subject of respiration[22] both in warm- and cold-blooded animals, in vertebrates and invertebrates. These studies were mainly published in 1803 after his death by his friend Sénébier, but possibly failed to receive as much credit as others of his works because he was not alive to defend them. His experiments range over a large field: confining animals in stagnant air and noting the effects; studies on hibernating animals especially when subjected to an excess of carbon dioxide; placing animals with or without lungs, or parts of animals, *e.g.*, ovaries, stomach, liver, intestine, in atmospheric air and observing how oxygen is taken up and carbon dioxide given off by these animals or by their excised tissues. As Stirling sums it up:

> Here, was a mighty stride forward: oxydation does not take place in the lungs, nor, indeed, in the blood. It is the tissues that respire, *i.e.*, consume oxygen and give off carbonic acid. Spallanzani had studied profoundly what we now call "internal respiration." Secondly, it is not the oxygen taken in on which the tissues live, and give out carbonic acid, for snails and "worms" give off this gas in an atmosphere of pure azote or hydrogen.[22]

His observations on the respiration of excised tissue only lack quantitative details to make them wholly modern in sound.

The field of reproduction in the animal kingdom claimed much of Spallanzani's attention and his studies included many on Amphibia—their mating habits, the process of fertilization and the development of the embryo—as well as on higher forms. In addition to watching the normal reactions, he investigated experimentally certain features of sexual behavior, especially the clasp reflex in Anura. Luciani quotes from the Genevan edition of 1876 by Sénébier the description of certain experiments.

[22] Foster, *loc. cit.*, p. 253; Luciani, *loc. cit.*, Vol. 1, p. 375; Stirling, *loc. cit.*, p. 72.

Finding two toads in copulation I separated them forcibly; I cut off the thighs of the male and put it down near the female; it then embraced her anew. I cut off the hands of the male toad and placed it near a female; as we know, the males use their hands in copulation; it seized the female with its bleeding stumps and did not release her till all the ova were fertilized. On cutting off the head of a male frog in the act of copulation, it did not let go of the female with its arms and hands; it bathed the ova for an hour and three quarters with its seminal fluid, and nearly all of them developed into tadpoles.[23]

In his contention that preformation occurred in the amphibian and other eggs, Spallanzani was led astray. In no uncertain terms he claims that the embryo exists in the egg, simultaneously eliminating the ideas of the "spermists" and aligning himself against any active rôle of the sperm cells. In that part of the "Essay on Animal Reproduction" called "On the Existence of the Tadpoles in Eggs before Fecundation," he compares the fecundated and unfecundated egg and failing to find any real difference between the two, decides that the embryo must exist in the egg as it passes down the oviduct before fecundation. After a description of cleavage and embryo formation, he writes:

Such are the phenomena, which gradually make their appearance in the fecundated eggs. Hence it must be obvious, that these are not properly, as was imagined before, the eggs from which the tadpole grows, but rather the tadpoles concentrated and coiled up in themselves . . . and . . . the tadpoles exist before fecundation and require only the fecundating liquid of the male to unfold themselves.[24]

As to the rôle which the seminal fluid really plays, he continues:

Before fecundation, the small heart of the germ wants force sufficient to overcome by its impulse the resistance of the solids. This force it receives from the fecundating liquor which stimulates, gently irritates, and obliges the heart to propel with greater power the fluids, through the smallest canals. The same liquid afterwards becomes nutritious, bringing about the development of the germ, which supplies nourishment.[25]

But he feels that these ideas do not fit the case in the development of the tadpole and becomes hopelessly involved in an explanation which really merits a rebuke as severe as those he administered to others.

Tadpoles, or if you please, the eggs of tadpoles, unfold themselves considerably before fecundation. One of these when in the uterus, is at least three times bigger than the same, while still attached to the ovaries. They are animals therefore, the germs of which are not disclosed at first by the spermatic fluid, but by the juices of the mother, and since this unfolding or increase of bulk is performed by nutrition, which must imply a circulation of fluids, and that such a circulation can not be carried on without the action of the heart, we are obliged to infer that these maternal juices are themselves that kind of stimulus which the seminal liquor is supposed to be in birds. Consequently the heart in the germ of the tadpole must beat sufficiently to produce a circulation of fluids, without an insuperable impediment from the solids.[25]

In the paragraphs which follow, he appears disturbed at the fact that these "tadpoles" perish unless fecundated and yet he can not quite assign any rôle to the seminal fluid. He finally takes refuge in a series of interesting but somewhat irrelevant questions.

Misinterpretations appear to run through others of his studies on fertilization. Although successful in artificially inseminating not only amphibian forms (terrestrial frog, water-newt, fetid terrestrial toad, tree-frog, green aquatic frog) but also a dog,[26] he persists in asserting that sperm cells are not the fertilizing elements proper, and even

[23] Luciani, 1917, *loc. cit.*, Vol. 4, pp. 78–79.

[24] Spallanzani, "Essay," transl. by Maty, *loc. cit.*, p. 42.

[25] *ib.*, pp. 45–46.

[26] F. H. Marshall, 1922. "The Physiology of Reproduction." 2nd ed. Longmans, Green & Co. pp. 174–175. Quotation of a contemporary English translation of Spallanzani's experiment.

after filtering seminal fluid, he claims that the filtrate alone is potent in fecundation. Why he should have interpreted his data in this way is scarcely to be understood both in view of experiments which demonstrated the reverse and his usually clear logic. As Lillie points out, Spallanzani deserves the credit for the pioneer experiments on artificial parthenogenesis because he tried "to start development of eggs, by electricity, by the action of extracts of all the various organs, by vinegar, dilute alcohol, lemon juice, and other substances," although with no success.[27] These experiments were all undertaken primarily to see whether other fluids besides the seminal one might accelerate the vital process, which he believed to be the rôle of the latter.

One problem which interested Spallanzani almost continuously in his career was that of spontaneous generation.[28] His chief opponents in this field were Buffon with his "organic molecules" and Needham with his "vegetative power." Although in reading Spallanzani's account of his work it is evident that there were some gaps in his experiments, it is certain that he was able to demonstrate the absence of animalcula in liquids contained in hermetically sealed flasks and sufficiently boiled, and Murray's claim that "Spallanzani had anticipated one of the most renowned of the experiments of Pasteur with results that would have satisfied the French investigator,"[29] seems fully justified.

Among less well-known experiments which he carried on are those on bats. In an attempt to discover how these animals avoid objects as they fly,

> he blinded the animal sometimes by burning the eyes with a red hot wire and sometimes by removing the organs altogether, and even filling up the orbital cavity with wax. Notwithstanding these mutilations, the little creatures were able to fly as well as before, avoid the walls, and the strings suspended in the path of their flight. These and other experiments led him to the conclusion that bats find their way in the dark by means of some special sense situated in an unknown organ on the head. It is now generally accepted that this astonishing faculty in bats of directing their flight is due to an exceptional development of sense of touch, especially in the wing membrane.[30]

Studies in other subjects, such as physics, chemistry and geology, consumed much of his time in the laboratory and in the field. He appeared to be equally at home in these branches of science, and in the travels which he undertook to add to the collections in the museum at Pavia, he was often forced to be both "naturalist and chemist." He revealed many times his ingenuity for conducting experiments when far from his laboratory, perhaps nowhere better portrayed than in his examination of the phosphorescence of certain medusae which he collected in the Straits of Messina. Besides studying the anatomy and physiology of these curious forms, he dried them, squeezed them into various liquids (water, urine, milk) and did many other things to test their capacity to give off light.[31]

> A single medusa of a moderate size, being pressed and shaken in two ounces of this milk, rendered it so luminous that I could read the writing of a letter at three feet distance. The duration of this phosphorescence was likewise greater than that of the water. After eleven hours from the time I first put the medusa into it, it still retained some light; and when that

[27] F. R. Lillie, 1919. "Problems of Fertilization." Chicago. pp. 6–9.

[28] F. H. Garrison, *loc. cit.*, p. 329; Spallanzani, "Tracts," transl. by Dalyell, *loc. cit.*, Vol. 1, p. 13.

[29] R. H. Murray, 1925. "Science and Scientists in the Nineteenth Century." London. p. 236.

[30] Cummings, *loc. cit.*, p. 240.

[31] It is interesting to note that Harvey (1920, "The Nature of Animal Light," Lippincott, p. 85) speaks of Spallanzani's experiments on phosphorescence as being of "great importance in understanding the nature of animal light."

ceased, agitation restored it, as did warmth, when agitation alone became ineffectual.[32]

While his "Travels" primarily record natural history observations in the widest sense, *e.g.*, erosion, rock formation, volcanic fires, lava flow, swordfish and coral fisheries, varying species of Amphibia and birds, the customs of people, and dozens of other items, they also give us delightful and picturesque glimpses of his adaptability to the exigencies of traveling.

The ascent up the steep and craggy cone of Etna, though not more than a mile in a direct line, cost me, as I have already said, three hours of laborious and fatiguing exertion. It seems scarcely necessary to say that the descent employed me less time, but the difference greatly exceeded my expectation. I found that to effect this descent nothing more was required, but to fix my feet firmly on some large pieces of scoriae, and balance my body, since that piece, from almost the smallest impulse I could give it, would slide swiftly down the descent, and convey me to a considerable distance, till stopped by the accumulation of the lesser pieces of scoriae which it drove before it; when I had only to select another large piece, on which I glided down as before; only taking care, with the staff I held in my hand, to turn aside the pieces of scoriae which followed me in my descent, that they might not strike against and wound my legs. In this manner, in a few minutes, I arrived at the bottom of that declivity.[33]

An equally interesting insight into the fundamental humanness of the man is the reward of a perusal of these volumes. He was poignantly aware of the people with whom he came in contact. He notes the tragedy in the lives of the folk who live near Etna and must go nearly ten miles for water. He responds with a ready gift to the child who broke his jug and had no money to buy another. He expresses his thanks to the priest who helped him when he was nearly shipwrecked, "a man towards whom I shall feel the warmest sensations of gratitude while life shall remain."[34] He records his genuine appreciation of the gift of some pieces of rare white coral from another priest.

Tucked away in the "Travels" is the following revealing comment by its author. "The powers of the human mind are so limited that it can never entirely exhaust the subject it investigates."[35] However, this consciousness of human limitations did not keep Spallanzani from delving into many fields of knowledge, and from making valuable contributions on many subjects. In fact, his versatility is both overwhelming and refreshing in these days of specialization, and what is perhaps most amazing in his researches is that he made relatively few mistakes in his manifold attempts to find out nature's secrets.

[32] Spallanzani, "Travels," transl., *loc. cit.*, Vol. 4, pp. 238–240.

[33] *ib.*, Vol. 1, pp. 287–288.

[34] *ib.*, Vol. 3, p. 130.

[35] *ib.*, Introd., p. viii.

PALEO-MALTHUSIANISM

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EARLIEST ideas upon the subject of population, gathered from the writings of ancient peoples, appear to be nothing more than articulated instincts, born of the struggle for existence. These ideas sprang from the innate feeling that one must prevail or succumb, and that one's kind must prevail or finally be obliterated. What Stangeland[1] calls "a religious veneration of procreative powers" expresses the general trend of early thought, though there is an occasional instance of what appears to be a contrary trend—where a restricted population seems to have been desired. On closer scrutiny, however, these cases frequently disclose another purpose.

The instinct to prevail, or—when it becomes rationalized—a war policy, seems to have been the central motive in all early population theories. Even during classic times, in Athens, in Sparta and elsewhere in the Hellenic civilization, what appears to be an indubitable restriction policy proves upon better understanding to be an early essay at the art and science of eugenics—looking mainly toward the creation of more effective fighting men and more efficient public servants.

Most of the Greek city states regulated minutely the lives of their citizens.[2] The regulation of marriage and celibacy was expressly prescribed. Marriage was not entirely a religious institution, nor was it held to be solely a personal concern; it was a semi-public institution, looking toward the production of sound citizens.[3]

Here, as in most matters, the Spartans were particularly thorough. This virile city state, so frequently engaged in wars that decimated her fighting men, put into effect every possible provision for the production of first-rate warriors. Marriage was compulsory. Bachelorhood was condemned by law and by public opinion. In pugnacious little Sparta, where so few escaped the sword long enough to attain to a great total of years, youth was not required to pay to elderly bachelors the respect customarily given to old age. Marriage was the honorable estate; celibacy was disgraceful. Here we find expressed, both in law and practice, the old instinct to persist—if not in person, then in progeny—but with characteristic thoroughness these Greeks added something, the eugenic idea. Not only did Sparta decree more children, but better children. Infanticide was practiced but more in consideration of quality than of numbers.[4]

The Athenian policy was more liberal. There were laws against bachelorhood, but in peace times they were evaded; in fact, late marriages were generally advocated. Here is probably the first palpable evidence of a new population policy—an expressed desire to restrict the number who share in the limited good things of life. Further evidence is not wanting. The Athenians, by encouraging emigration and by permitting the practice of infanticide, expressly recognized the constant fact of overpopulation. We find then in Athens a middle policy, marking a transition from the program of unlimited expansion—the program of poor and war-like states—to the out-and-out restrictive policy of

[1] C. E. Stangeland, "Pre-Malthusian Doctrine of Population," p. 16.

[2] H. Blumner, "The Home Life of the Ancient Greeks," p. 177.
Rostovtzeff, "A History of the Ancient World."

[3] G. W. Botsford, "Hellenic History," p. 409.

[4] *Cf.* E. B. Reuter, "Population Problems," pp. 40–42.

rich, populous and peaceable states—a bridge between ancient and more modern ideas on population.

But in defining Athenian population policy, the practice of infanticide must not be taken too seriously. It was first of all a eugenic measure, and secondly, a means of personal convenience. It must, however, be taken, in part, as indubitable evidence of a restrictive population policy, for we find among primitive peoples that, wherever originally easy living conditions brought forth a swarming population, infanticide was practiced. In Polynesia it was at one time quite general. In Hawaii children after the third or fourth were strangled or buried alive. Tahitian fathers had the right of doing away with the newly born. In the Society Islands infanticide was imposed upon women by oath.[5]

Plato, in his philosophy, provided for a careful regulation of population—to preserve social equilibrium. His state was to consist of a limited number of citizens (5,040). If the number began to decrease, prizes might be offered to encourage the growth of population; if there was excess, colonies could be developed.

Aristotle's program was almost exclusively negative and restrictive. The number of children was to be strictly regulated. Exposure was to be the fate of ill-formed or superfluous children. Pregnant women who had already borne the legal number of children were to be relieved of their burden.

The Romans absorbed Athenian ideas in the field of population as they did in nearly every other field of human interest; Rome added nowhere to Greek ideas—except in agriculture and in making war. The Greek culture and people spread and conquered, but conquest was not a principal aim. Students of Greek antiquity maintain that perfection was the pole-star of the Greek culture. There is no mistaking, however, the Roman philosophy and program of conquest and expansion.

The population policy of the Roman Empire was exactly what a policy of military conquest invariably demands: an unlimited expansion of population and all possible encouragement for the production of new citizens and worthy fighting men. As early as A. D. 10 the *Lex Papia et Poppoea* was enacted—mainly through the efforts of two bachelor consuls—for the purpose of encouraging marriage and legitimate fertility in Rome.[6] Here, as in Greece, marriage was a semi-public institution—with the primary purpose of producing worthy citizens. Strangely enough, the families of the upper classes were not very large, and we can conclude that patricians who preached one policy in the forum practiced its opposite in private. Official policy, however, was clear: marriage was encouraged by rewards and amenities; bachelors were taxed. But as time went on these regulations seem to have had little effect. The burden of large families began to bore the later and more urbane citizenry of Rome.[7]

Romans then were latitudinarian in their views on marriage. The austerity and the socialistic ideas of the Greeks were wholly wanting—or they were represented by a few legislative gestures, more scoffed at than observed. Ineffectual legislative jack-o'-lanterns for bachelors were hung out by the later emperors. Julius forbade unmarried women of more than twenty-three years jewelry and other luxuries, and he rewarded those who bore many children. Campanian lands might be held only by the fathers of at least three children.

[5] *Cf.* A. M. Carr-Saunders, "The Population Problem," pp. 147–149.

[6] E. M. East, "Mankind at the Crossroads," p. 45.

[7] C. E. Stangeland, "Pre-Malthusian Doctrine of Population," p. 30.

Most of the commonly assumed population policies of Rome, at least those which found expression in the laws of the later emperors, were anti-vice regulations, or provisions for the continuance of patrician families. Under the Emperor Augustus an elaborate code was enacted, looking toward (1) the preservation of class and privilege by forbidding persons of senatorial rank to marry persons of lower caste, (2) the promotion of marriage by handicapping legally the unmarried, (3) the further encouragement of marriage by granting legal and political advantages to married parents, (4) the further handicapping of unmarried persons by abridging their right of inheritance. These laws were, however, of little effect, not so much because upper-class Romans wished to avoid the burden of child-rearing but because they wished to indulge in all manner of irregularities. Finally, putting aside anti-vice legislation and laws designed to preserve class and privilege, we find the policy expressed by the remaining laws dealing with population to be the one made familiar by Roman literature and philosophy, a policy of expansion springing from the old instinct to prevail plus a reasoned policy of imperialism.[8]

The instinct to survive through sheer force of numbers seems to have been general among primitive and primordial peoples. So fundamental an instinct could not fail to find reflection in religious doctrine and practice. Professor Patten[9] and Dr. Stangeland[10] find that it did. In fact, primitive religions often made a fetish of the procreative act and gave it a central position in their ritual and doctrine. Of this Dr. Stangeland has to say:

> While it would be going too far to claim, as some writers do, that most, or even all, religions had a purely phallic origin, it can not be controverted that so-called phallic ideas have played a great part in very many early religions and religious ceremonies. The reproductive and fructifying powers of man naturally aroused his awe and reverence.[11]

Eroticism finds expression not only in the crude religions of primordial peoples[12] and primitive modern tribes, but also in the great philosophical and poetical religions of the East which have made themselves felt in effective opinion down to the moment that is passing. Bel, the supreme God of the Assyrians, was the great procreator. His wife Mylitta symbolized the reproductive passion of nature; she bore the title, Queen of Fertility. Hebrew scripture is full of the propaganda of prolificity; in fact, the first injunction of Jehovah to his highest and final work of creation was to "be fruitful."

The Brahmans affected celibacy as did the fathers of the early Christian church, but unlike early Christians they did not hold marriage in contempt, nor did they recommend abstention for the commonality of people.

The views of early Christians find a harmonious note in the asceticism of the precepts of Buddha, but as with Brahmanism, these precepts hardly touched the lower classes of their adherents.

Confucius' views very nearly coincide with those of the ancient Hebrew prophets and law-givers. His doctrine favored the expansion of population; he held that the man who died without sons died without honor.

Zoroaster pronounces with full, clear voice the precepts of productiveness in

[8] Varro, Ap. Macrob. "Saturn.," I, 16.
Horace, "Carmen Saeculare": "Diva producas subolem patrumque prosperes decreta super jugandis feminis prolique novae feraci lege merita."
Pliny, "Epistolae," vii.
Livy, Lib. i, Cap. 9.

[9] "Development of English Thought," pp. 132–133.

[10] "Pre-Mal. Doctrines of Population," pp. 40–44.

[11] *Op. cit.*, pp. 42–43.

[12] Westropp and Wake, "The Phallic Idea in the Religions of Antiquity," pp. 27 *ff*.

the Zend-Avesta: "Verily I say unto thee, O Spitama Zarathushtra! The man who has a wife is far above him who begets no sons; he who keeps a house is far above him who has none; he who has children is far above the childless man."[13] Herodotus tells us that in his time prizes were given in Persia by the king to those who had most children. Sacred texts of the Pehlevi period expressly declare that "He who has no child, the bridge of paradise shall be barred to him."[14] Mohammed seconds this doctrine—even exceeds it in recommending polygamy. He commands that special respect be paid to wives and mothers. (Stangeland, curiously enough, seems to hold that polygamy is less fruitful than monogamy, but he here is in face-to-face conflict with Mormon doctrine and experience.[15] Possibly he confused polygamy with polyandry or with promiscuity.)

Egyptians, Greeks, Romans and other Mediterranean peoples—but especially the Egyptians—in their religious thought and exercise held the reproductive powers in greatest esteem. Everywhere a prominent god or goddess represented the reproductive principle: in Egypt, it was Khem; in Assyria, Vul; in India, Siba; in primitive Greece, Pan—later Priapus; in Italy, Mutimus; in classical Greece and Rome, Venus, Priapus, Bacchus, Lucina.

Pilot's charitable, or at least agnostic, attitude at the trial of Christ, and Christ's previous pronouncement of allegiance to Rome, "Render unto Caesar the things that are Caesar's and unto God the things which are God's," to the contrary notwithstanding, Christianity was interpreted, both on the Roman and on the Christian sides, as a revolt, if not against Rome, then against a great many things Roman—and among others the low moral tone of the cosmopolis, especially in the matter of sex relations.

For early Christians, the celibacy of Christ and the virginity of the Holy Mother were ever-present symbols of a universal propaganda against prolificity. It was not, however, the austere scorn of the Brahman, it was not the preoccupied unconcern of the high-caste Mohammedan who was preparing himself, or his spirit, for a better life on earth—or somewhere not far off—it was the complete indifference to earthly acts of one who expected to migrate shortly to a happier and distant sphere. This was the teaching of Paul, the early church fathers and medieval Christians. Methodius says:

> For the world, while still unfilled with men, was like a child, and it was necessary that it should first be filled with these, and so grow to manhood. But when thereafter it was colonized from end to end, the race of man spreading to a boundless extent, God no longer allowed man to remain in the same ways, considering how they might now proceed from one point to another and advance nearer heaven, until having attained to the greatest and most exalted lesson of virginity they should reach to perfection; that first they should abandon intermarriage of brothers and sisters and marry wives from other families; and then that they should no longer have many wives, like brute beasts as though born for the mere propagation of the species; and then that they should not be adulterers; and then again that they should go on to continence, and from continence to virginity, when, having trained themselves to despise the flesh, they sail fearlessly into the peaceful haven of immortality.[16]

Sir Thomas More in his "Utopia" takes a stand midway between Methodius and Luther—a view that was filched, we suspect, from Plato: "Lest any city should become either too great or by any accident be dispeopled, provision is made that none of their

[13] Z. A. Ragozin, "Media, Babylon, and Persia," p. 123.

[14] *Loc. cit.*

[15] C. E. Stangeland, "Pre-Mal. Doc. on Pop.," p. 49.

[16] Methodius on virginity, recounted in H. Wright, "Population," p. 6.

cities may contain more than six thousand persons besides those of the country round."[17] Plato in his Utopia recommends, we recall, five thousand and forty people. But good Sir Thomas apparently counts upon a terrific death-rate: fourteen out of every sixteen children must meet an untimely end if each couple is only to reproduce itself, for he says: "No family may have less than ten or more than sixteen children, but there can be no determined number of children under age."[18] But with the appearance of Luther and the Reformation, rising reverberations merged in a clear, unmistakable and wholly different note. From that time forward, Christians and the people of Christian civilization took their population policy for four centuries or more from the Old Testament, from the Pentateuch and especially from God's command to his first-made man. Luther sounds the full note of unlimited expansion:

> It is only necessary that we work and do not remain idle; we shall assuredly be both clothed and fed. . . . From all this we draw the conclusion that whoever finds himself unfitted to remain chaste should make arrangements betimes, get some work and then dare, in God's name, to enter into matrimony. A youth should marry not later than his twentieth year, and a maiden when she is between fifteen and eighteen years old. Then they should remain upright and serious and let God provide the way and means by which their children shall be nourished.

In another place good Luther says, "If women bear children until they become sick and eventually die, that does no harm. Let them bear children till they die of it; that is what they are for."[19] This is the view of the "he-Christian" intoxicated by the poets and *cognoscenti* of Hebrew scripture. This, with the military accompaniment of rolling drums and blaring trumpets, is a very ancient hymn to those genial gods who whisper in the ears of solemn males that the procreative act is a religious duty—willy-nilly.

The Thirty Years' War, which decimated the population of the heart of the continent of Europe, and the rise of Louis XIV and his like to play a while at the engaging game of Grand Monarch, brought a need for cannon fodder —for many men, brave or not brave, sons of otherwise happy peasants and happier gentry who might serve as chips, white, blue or gold, in this expensive and correspondingly gratifying play among the *L'état-c'est-moi* players.

But before the arrival of the Grand Monarchs and their successors, the Great Powers, there was a period of desiccating poverty which produced in Bacon and Sir Walter Raleigh a conservative strain. Raleigh, even when discoursing upon war, said:

> When any country is overlaid by the multitude which live upon it, there is a natural necessity compelling it to disburden itself and to lay the load upon others, by right or wrong, for (to omit the danger of pestilence, often visiting them that live in throngs) there is no misery that urgeth men so violently unto desperate courses and contempt of death as the torments and threats of famine. Wherefore, the war that is grounded on general remediless necessity, may be termed the general and remediless or necessary war.[20]

But usually militarists held no such apologetic view.

German theorists of the time and later, mostly court stewards or *Finanzminister* with a philosophical turn of mind, economists to an extent—called Camerialists—fell in with the militaristic procession, and urged policies of population expansion.[21]

[17] Sir Thomas More, "Utopia," p. 102, "Ideal Commonwealths."

[18] *Loc. cit.*

[19] Preserved Smith, "The Age of Reformation," p. 509.

[20] Sir Walter Raleigh, "Doctrine Upon War in General."

[21] L. H. Haney, "History of Economic Thought," pp. 188, 147, 148.

The Mercantilists, another school of pre-economics economists, prescribed expanding populations. The rise of great powers and of mercantilism are merely the economic and political aspects of one and the same phenomenon. Huge states competed for the material good things of life and for the privilege of exploiting the alleged backward peoples of the world. For three hundred years the pale men of the earth outdid each other in seizing and in plundering. All this took men and money, but mainly men. The sages of the hour, who for the first time in the history of the world were in their several individualities one and the same person with the merchant princes, wrote very engaging essays setting forth the glories of large families. William the Third, heeding their advice, taxed bachelors, as did Colbert—Louis XIV's unexampled master of extortion. British colonial legislation a little later had a like inclination; for example, the colony of Maryland enacted that unmarried men, more than twenty-five years old, and childless widowers of the same age should, in certain circumstances, pay a tax to be applied to the support of foundlings. Prussia at this time required marriage before the age of twenty-five, and subsidized the institution. Maria Theresa of Austria broke tradition and permitted soldiers to marry. In 1767, she decreed a bounty to sergeants, corporals and common soldiers of three *kreutezri* per diem for each legitimate child.[22]

Writers and theorists to justify such programs were not wanting. The motive expressed in theory and practice alike was plainly an extension of the instinct of self-preservation, a desire for world dominance, a militaristic doctrine; argument nevertheless ran in economic terms. These theorists, doctrinaires, observers and writers noted that where wealth was abundant there were people in great numbers; and they came by an easy pathway to the conclusion that more people meant more wealth, that if a nation or a great city wished to be wealthy, it must encourage the multiplication of population. Truth, of course, runs in a direction exactly opposed to their stream of thought: the existence of great wealth, or the existence of unusual facilities for the development of great wealth, draws an abundant population.

John Graunt (1620–1674) in his "Natural and Political Observations Upon the Principles of Mortality" says:

> Now forasmuch as princes are not only powerful but rich according to the number of their people (hands being the father as lands are the mother and womb of wealth) it is no wonder why states by encouraging marriage and hindering licentiousness advance their own interest as well as preserve the laws of God from contempt and violation.[23]

Sir William Petty (1623–1687) spoke unmistakably in favor of the multiplication of population, and considered it the most definite sign of prosperity. In his "Political Arithmetic" he recognized a relationship between the growth of wealth and the growth of population. In his "Treatise of Taxes and Contribution" he associates population and wealth more definitely, giving population a causal character. "Fewness of people is a real poverty," says this noble scholar, "and a nation wherein are eight millions of people is more than twice as rich as the same scope of land wherein are four." John Locke seconds this opinion—though Locke's vigorous individualism made him more nearly the father of the natural liberty or physiocratic school of economists than a follower of the mercantilists, from whose technique physiocracy was in part, of course, a reaction.

[22] C. E. Stangeland, "Pre-Mal. Doc. of Pop.," pp. 124–126.

[23] P. 70.

Thomas Mun (1571–1641), merchant prince and popular pundit of political economy, was one with his mercantilist colleagues in advocating swarming populations: "For when the people are many and the arts are good, there the traffic must be great and the country rich."[24] Samuel Fortrey (1622–1681) and Sir William Temple (1628–1699) follow the crowd: "The true and natural ground of trade of nations is the number of people in proportion to the compass of the ground they inhabit."[25]

Sir Joshua Child (1630–1699) was an ardent believer in the advantages of a mounting population. He felt quite certain that an increase in numbers meant increasing riches, and that any decrease in population would bring about a decrease in wealth. In brief, all the great mercantilists recognized a direct relationship between population and wealth, but all of them put the cart before the horse: all of them held that population was cause and wealth, effect. Sir Charles Davenant (1656–1731), McCulloch and Adam Smith, however, seem each to have gained a progressively clearer insight into the correct view that wealth was the cause and population the effect.

Benjamin Franklin, who was born an Englishman but afterward became an American citizen, was in thought and spirit always a Frenchman. Nowhere—not even in America—was he so fully appreciated as in France. Franklin was greatly influenced by the then current school of French economists, the Physiocrats. The great American sage, in his "Observations Concerning the Increase of Mankind and the Peopling of Countries," says something which sounds very much like Malthus:

> There is no bound to the prolific nature of plants or animals, but what is made by their crowding and interfering with each other's means of subsistence. Were the face of the earth vacant of other plants, it might be gradually sowed with one kind only, as, for instance, with fennel; and were it empty of other inhabitants, it might in a few ages be replenished from one nation only, as, for instance, with Englishmen.[26]

Here undoubtedly is the most significant writing upon the subject of population or upon the much broader subject of biology, for that matter, before Malthus; for Franklin's principle, if not the actual progenitor of the cataclysmic ideas of Malthus, Darwin and Wallace, contained their essential element.

In 1776, the first year of American independence and the year of the first practical substitution of steam-power for man-power, Adam Smith issued his great work, "The Wealth of Nations." Smith, like Holy Writ, is notorious for furnishing quotations to any devil who passes: Karl Marx's thunder is an echo from the "Wealth of Nations," nevertheless it has been a rich source-book for reactionaries in every land. Smith's pronouncement upon population possesses this same dual character.

But in the main, Adam Smith takes the view of the out-and-out mercantilist, the militarist, the churchman: "The most decisive mark of the prosperity of any country is the increase in the number of its inhabitants." Farther on, however, we find the slightly Malthusian pronouncement: "Countries are populous, not in proportion to the number of people whom its produce can clothe and lodge, but in proportion to that of those whom it can feed," and then what seems to be the very essence of Malthus' great essay, "Every species of animals naturally multiplies in proportion to the means of their subsistence

[24] Sir Thomas Mun, "England's Treasure in Foreign Trade," p. 12.

[25] Sir William Temple, "An Essay Upon the Advancement of Trade in Ireland," Vol. III, p. 6, of "Work's" (1757 ed.).

[26] "Works" (Bigelow edition), p. 347.

and no species can ever multiply beyond it." As an effective basis for the great Darwinian hypothesis which, as every schoolboy now knows, was filched directly from Malthus, this statement is, however, wholly inadequate—in fact, it is the exact opposite of the Malthusian thesis: all species tend to multiply *beyond* the means of their sustenance—whereas Smith says, "No species can ever multiply beyond the means of their subsistence." This was the last significant voice heard before 1798 when the great essay on the principles of population was uttered by Malthus.

Hume, Wallace, Dr. Franklin and Adam Smith—these were teachers of Malthus, but pupil exceeded masters. William Godwin, the latter day saint and proponent of perfection, was the man who incited the revered, and ordinarily mild, Mr. Malthus to break into argument with his father, who was an ardent Godwinite and a follower of Rousseau. The elder Malthus and Godwin, with their irrepressible and distressing optimism, stirred in young T. R. Malthus a bit of irritability which gave the world—if we remember the debt of Darwin and Wallace—the most influential piece of writing to which it has ever fallen heir. For upon its central thesis (life everywhere tends to exceed the warrant for it) rest principal propositions in nearly all departments of modern philosophy and science.

A BLACK BEAST IN OUR EDUCATION?

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At a recent conference upon the scientific study of young children—a conference of leaders from the United States and Canada — the presiding officer warned the members against an attempt to get rid of crime. He believed that such an aim would bring danger of utter fixity, of utter stagnation, in the country. And he had in mind, I know from immediate conversation with him, President Hoover's call upon America to become a law-respecting instead of law-flouting nation. Another member of the conference, one of the most distinguished of the women present, who had recognized the need that children should early adapt themselves to the requirements of their society, aroused instant opposition because of this restriction upon the child's full liberty. Under fire, she at once protected her position and agreed that in teaching the child to obey law, the child must above all be taught to know when to break law.

Such views, even if extreme, illustrate a trend in American education in the home, in the school and in the larger community. It has long been with us, giving color to the opinion of foreigners that we have the world's worst-behaved children. Indeed, we should probably have to go to the Eskimo to find boys and girls as self-willed as ours. The national commission to report to the President upon the violation of law in America will of course look into, but also beyond, the laws themselves and the lawyers, judges, police and the procedure of our courts. If thorough, their observant eye will stay long with the children, and not simply with delinquent children. For the attitude even in those who keep the laws, an attitude established in early life, is important. An attitude in the public generally toward law, toward all restriction of individual liberty, affects our education, which in turn confirms the attitude in the public generally and invites license.

Now this trend in our education has received fresh impetus from studies of repression. Under the influence of Breuer, Freud and others this field has been given a new significance for mental and physical health and for emotions and for character itself. And in consequence there has come the desire to rid the young of their harmful repressions, to avoid a paralysis of the youthful spirit, to encourage initiative and the free expression of personality. Behind this massed attack upon evils too often in the family and in the schools, evils which all liberal minds will wish destroyed, there is an eagerness for a new form of liberty.

And yet in this right eagerness, we might receive the new sensibly. We might contrive, like an older child, to hold things in two hands at once. In our impulsive delight in the novel benefit from unrepression—especially when this chimes so well with our national zeal for freedom—we may find ourselves like a hungry and thirsty dog that, suddenly coming upon water, drops his bone in the deep pool to drink and then discovers that he still is hungry.

Now in the admirable ardor for individual freedom and self-expression in childhood, one too often misses an equal ardor for the conditions which make for freedom and self-expression. One might imagine, from the long tale of wrongs wrought by parents and teachers, that the happiest place for the personal development of the young would be the jungle. Fortunate the child, one might believe, whose wise father and mother had in infancy abandoned it to wolves or apes. But such jungle children as are actually observed, say in India—are they

of all the young the freest in their powers, liberated, clear-eyed, masters of their fate, captains of their souls? On the contrary, they seem more like beasts than men, without the human gait, mentally like imbeciles. They seem to have nothing of personality to express, and no means to express this nothing. Kipling's Mowgli of the "Jungle Book" is a noble figment of an unprecise imagining. It is neither fact nor truth. Romulus and Remus, if given no more than their native impulses, trained after the manners of their foster-mother, would have been impossible founders of the Eternal City and of that great Roman culture of justice through law which changed the face of Europe and America.

The truth is, that spiritual attainment is only in part to be prepared for negatively, by removing inhibitions, by avoiding repression. The qualities which are most valued in the person—his intellectual penetration; his escape from superstition; his creative power in arts such as literature, painting or music; his tolerance of opposition; his broad interests and sympathies; his contempt of lies; his unswerving loyalty to child, wife, country, humanity; his readiness to go to the stake or the block or to drink hemlock, for his scientific or moral or religious convictions—these are not to be had merely by removal of external obstacles; the man, the woman does not spontaneously come into these great traits by sheer individual growth or maturing. On the contrary, along with the removal of external obstacles and with the happy growth, these things come only by creative achievement in a community whose eyes, generation after generation, are fixed upon their achievement, and who invite and praise and whip one another onward in the great corporate enterprise. This is why no Dante, no Darwin, no Beethoven steps forth from the jungle. Liberty is not enough. Ages of constructive work by men and women forgotten entered into the great attainment by these and all other geniuses. Creative power obtains its knowledge, its skill, its interests, its aims, its appreciations, nine tenths from others. The personality that comes to such original expression is nine tenths a creature of the spiritual city in which it lives. Both genius and talent, to change Goethe's saying, require the storm of the world. Even your relatively detached critics, like Descartes and Voltaire, are no less the children of a surrounding and sustaining enterprise than are the more attached geniuses like Wesley or Lincoln.

In our American life and schooling we rightly recognize the evils of repression, but we need not think it the blackest of beasts. Most of us who are healthy can stand much repression—finding it uncomfortable, perhaps, but without lasting damage. I sat by a lady at dinner a few days ago who spoke to me bitterly of her early training. Her childhood had been so repressed by a rigid Presbyterianism that when recently she was in Geneva she could take no pleasure in the Reformation Monument there, with its stately sculptures, its inscriptions, its noble planting, because she discovered John Knox among its heroes; and in Edinburgh, as she passed his house on the High Street, she could only stick out her tongue at it! I listened sympathetically; I was glad that I had escaped her kind of training. And yet I could not but see that, with all the wrong done her childhood, hers was not a frustrated personality. She had done and was still doing enviable things. Her early discipline, dour as so much of it was, had given her far more than it had taken away: she knew and loved things honorable, she was both zealous and sane in her work for social betterment, and had subjected her high intelligence to a training which had given her an expert leadership recognized by all those in her kind of work throughout the nation. She undoubtedly had been made less happy, but had not been crippled by

those early years. Unfortunate as they were, they were ten times less unfortunate than would have been the untrammeled life of the gutter snipe.

The slight damage which the normal person usually receives from such repression as is part of intelligent and fairly sympathetic discipline can be seen if we look to a larger company. It has long seemed clear that ministers' sons generally go wrong; cases in plenty can be cited by any one; and it stands to reason that it must be so, for these lads are made rebellious by home austerity. And yet, the facts, when gathered impartially and on a wide scale, show the very opposite; show that ministers' sons are in a highly favorable situation. What an actuary might call their "expectation" of becoming distinguished is better than that of most others' sons. Above the children of laborers, farmers and artisans, in this respect, come the children of business men; and above these stand the children of professional men. And within this highest class the sons of clergymen are no whit behind the rest. Even doctors and lawyers give no higher quota of children who come to attainment. In spite of the economic straits in which clergymen's families are reared; in spite of what the anti-repressionist might call their utter damnation from snivelling Presbyterianism, Baptism and Methodism, the ministers' households have proved to be nurseries of talent; in general, we have contrived none better. Repressions have been there on every hand. To the unpenetrating observer the air seemed heavy and stifling, from basement to attic. And yet something was present in the homes of these children which really gave them freedom, liberating in them what their fellows were to recognize and praise. Repression, then, while always uncomfortable and sometimes disastrous, is not the great source of disaster; it is not the reef on which most lives are wrecked. It is not the one fact in childhood to be feared above all else.

Obviously repression is not the chief cause of crime; although in saying this, one stems a latest current of the tide. The trends of thought here shift twice daily, as though controlled from the moon. Only yesterday was law-breaking attributed mainly to degeneracy with certain clear physical marks. But this theory suffered because too few criminals and too many law-abiding persons had these very marks of degeneracy. Then crime, it was said, is due first of all to poverty. Yet too often we find young violators whose parents are by no means in poverty; indeed, America, the wealthiest, the least necessitous of lands, leads the world in crime. Still later the cause is thought to lie in lack of intelligence; until facts put this, too, in its place. For too many of our criminals, young and old, have as high intelligence as those who obey the laws. The most of criminals indeed have an endowment of intellect quite adequate to lawful living in our civil order.

At the moment, we hear of repression as the chief cause of crime, especially in the young. At the annual convention of the National Parent-Teachers' Association in New York recently, a professor of sociology spoke in the newest vein, telling the great gathering of delegates, more than a thousand strong, that the excesses found in the youth of to-day are but a protest against coercion in home and school. And at the far smaller conference of experts in child development, already mentioned, the same thought was expressed, that delinquency is due chiefly to repression.

Now if this were true, if in this the chief cause had really been disclosed, then America should be the most law-abiding of lands. For our children in home and school are the least repressed in the world. And it is precisely our young criminals who have experienced

for the most part less than the least parental repression among us. The great part of them have known no real home at all, but early were waifs and strays.

And here we come into view of the one most important of all the causes. Other facts doubtless weigh—inferiority of physique, poverty, feeble-mindedness or mental disease—but the one fact which by direct observation in school and juvenile court enters oftener than any other is a lack of such training as comes from the normal home. This training is not mere knowledge, to be picked up in the house or street or newspaper or public library. It is not to be had, one regrets to say, in school, even in the advanced school; for the graduates of high school or college or university may not have received it, and far too often despise the social order. The unbroken home is its chief single source; and with all the charges to-day against homes and parents, no equal substitute has yet been found for the plain home and the plain mother and father. Unnecessarily and even harmfully they may repress; and yet commonly they more than offset whatever damage comes from their repression. The more profound and permanent injury to the child comes, not from the normal home or school, but from those cracked shells of home and parentage where the child finds the least restraint and is trained into no sure habit and purpose. He goes through life with chaotic impulses, which once might have been given form and beauty.

We may quite properly be afraid, then, of repression, but still more may we fear weedy personal growth without repression and guidance. Indeed in our present education, behind which is our traditional zeal for liberty, the greater danger is that we shall over-prize personal freedom and under-prize the benefits which come only from a civilized social order itself. In our lower and higher schools we are tolerant of slovenly conduct, speech and thought because these seem to betoken independence and self-resource. And because law-breaking seems a sign of this same admirable attitude, we are too little repelled by law-breaking and unwittingly foster it. Crime in quite extraordinary amount springs from the practical bearing so common with us, namely, that each person may properly regard himself as the supreme fact, for which the rest of the world is but a limiting condition. Men, women and things, he feels, are but stimuli for his responses.

We shall never be radical toward law-breaking until we destroy these roots; or rather, until we grow others strong among them. In school and home we shall have to give our youth a rooted attachment to the heart of the social enterprise itself. At present among teachers, scientists and laymen, the person is encouraged to see in the order and institutions of society but flimsy conventions, to be brushed aside like cobwebs in his way. He becomes boorish toward the subtle assistants of his life. He grinds his hob-nails into the most delicate fabrics of the spiritual loom. All things but his own crude spontaneities he regards as "bunk." Our educational creed in the quarters fashioned by a one-sided individualism is to-day as narrow as those creeds of Protestantism yesterday in which the individual thought of little but himself. It all bears a repulsive egoism. Mr. Haldane has recently said that the self-made man of America seems to the European somewhat ruthless. One may venture to think that there is a certain ruthlessness in Americans not self-made but shaped by our schools and by our American spirit generally. We have never as a nation quite reconciled liberty and law, but each man is airy toward any regulation inconvenient to himself. Americans are not convinced of the need—and the teacher-leaders most in vogue are taking away what little conviction there is of the need

—of loyalty toward such culture and cultural institutions as we have attained, still defective though they are.

For only by a cultural order which centuries and millenniums were needed to create, and by the institutions of such an order, do we attain the very individuality, the very originality we prize. The eminent danger with us—not only to our laws, but also to our success in literature, art, morals and religion—lurks in the ruthless form of our individualism—a form essentially wasteful of the individual because he is left untrained in expression and without substance to express. In those regions where we Americans succeed most impressively — in wealth-making, in architecture and in science—our success comes by another attitude, not by swagger of individuality, but by individuality essentially moderated, tempered into respect for an order of things beyond the individual. Our marked achievement in amassing wealth, in building and in scientific discovery and application has come and comes from creative individuals, but from individuals who have had to submit to a great order outside themselves; who consent to it and find their consent is not an enemy but a friend to their self-expression. By their very submission, strange to say, they find themselves enfranchised and given the freedom of the realm.

This attitude to be observed where originality most thrives is seen to involve an essential repression, but a repression which because it is in some deep manner accepted and approved and knit without rift into the personal structure is also without lasting protest and paralyzing rebellion. The weedy impulses—of the merchant to take what he wants, regardless of trade principles and ownership; of the architect to build without heed of cost or use; of the scientist to follow his own sweet will and peer into things irrespective of their significance for other minds, and to explain irrespective of other facts and of the canons of induction—these weedy impulses, where we have achieved most, have been handled in a manner which Rousseau and Professor John Dewey and their near or distant followers might with difficulty approve. The native impulses have been given an unnatural form, a form of social art. The spontaneous here has thrived, but has had to make its peace with an external law and order.

Our education, if it is to come to fruition, then, must recognize how glib and shallow is much of the patter about restraint. There are repressions and repressions; and of some we must get rid, and to others we must add strength. There is no place here for wholesale dreads and rejections. At a certain point one must plant his intellectual feet, and like some old schoolman abruptly say *distinguo*. The undiscriminating talk to students, parents and teachers—as though children burst into bloom by mere removal of constraint—such talk comes of loose thinking, of inexact observation and of that glamour which a kind of anarchy has for some noble minds. The spiritual anarchist for whom all external law is bondage has a good case, but hardly good enough. America surely need not stagnate or become enslaved merely by becoming more respectful of law, whether it be in home or school or nation—she with her larger margin of safety in this respect than any other country. She can become even more free and creative, and at the same time more order-loving. And only by education can this be done. So that the outlook will be dark indeed if teachers and parents are bedeviled, by a limited truth of psychology, into a panic fear of all governance of the child. The least repressed of peoples need not make repression their bugbear. The very freedom of the young can not be attained except by what must involve some repression; and if this becomes our *bête noire*, we are apt to diminish rather than increase the full round of things propitious for our children.

SUNLIGHT AND ITS MANY VALUES

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Dove non entra sole, entra il medico.—Italian proverb (Where the sun does not go, the doctor goes).

THE sun has ever exerted a profound influence on mankind. To the race in childhood the sun was a god. In the old mythologies the sun was personified and given human attributes. It was also believed to be the chariot wheel of a vehicle driven by the sun-god, Phoebus Apollo.

Sun worship is not a thing of the past altogether. There is yet extant a religious sect in Persia that still adheres to the practice. The American Indian still carries on his sun dance and prays to the great Sun Power. The soulful prayer of the Shoshone chief living on a reservation near Pocatello, Idaho, reveals the faith held in the potentialities for happiness and health possessed by the sun:

> Great Sun Power! I am praying for my people that they may be happy in the summer and that they may live through the cold of the winter. Many are sick and in want. Pity them and let them survive. Grant that they may live long and have abundance. May we go through these ceremonies correctly, as you taught our forefathers to do in the days that are past. If we make mistakes pity us. Help us, Mother Earth, for we depend upon your goodness. Let there be rain to water the prairies, that the grass may grow long and the berries be abundant. O Morning Star, when you look down upon us, give us peace and refreshing sleep. Great Spirit, bless our children, friends and visitors through a happy life. May our trails be straight and level before us. Let us live to be old. We are all your children and ask these things with good hearts.

Sunshine is a very old remedy. The same instinct which led ancient people to worship the sun as a god led them also to a belief in the therapeutic value of sunlight. Since the earliest times men have recognized the value of sunlight in the prevention and treatment of disease. The ancient Egyptians recognized sunlight as a healing agent. On the island of Cos in the Greek Archipelago, where Hippocrates, the father of medicine, practiced, the citizens erected a health temple and dedicated it to Aesculapius, god of sun, medicine and music. The colossal statue at Rhodes was a monument to the sun-god, Helios. The Romans built sun parlors without windows. Coelius Aurelianus, a Roman physician, advised the use of sun baths in chronic affections. To Pliny has been attributed the statement: *Sol est remediorum maximum.*

Oribasius of Pergamum, who lived during the last quarter of the fourth century and who was the physician of Julian, quotes Herodotus as follows:

> The sun is especially necessary for people who need restoration and the increase of their muscles; yet one must be careful of the rays which first pass the clouds, and avoid the rays which collect in places protected from the wind. One must further take the precaution that in winter, spring and autumn, the sun strike the patients direct; in summer this method must be avoided with weak people; the head must be covered during the treatment.

From this interesting statement it seems that the Greeks had laid down specific directions in the sun treatment of the sick. The use of sunlight as a therapeutic agent was known to the Arabians. Avicenna, the famous Arabian physician, who was a poet and who is believed to have participated in creating the Rubaiyat, also favored sun treatment in disease.

The method of treatment through sunlight was sooner or later discarded and sank into oblivion. It was revived again about the eighteenth century. Unfortunately, it was at that time regarded as a means to be used only by the quack. To illustrate the regard in which heliotherapy was held, we may cite the case of a physician well known in his day, Dr. Lettsum, who prescribed sun baths in the treatment of tuberculosis. He founded the Royal Bathing Hospital at Margate, an institution for the treatment of surgical tuberculosis, which still continues its beneficent activities. He received from his colleagues nothing but laughter and derision. There is a little poem about him that indicates their attitude.

> When patients come to I
> I physics, bleeds and sweats 'em
> And if they choose to die
> What's that to I? I Lettsum.

In 1774 Faure advocated exposure to sunlight for the treatment of chronic ulcers of the limbs. In 1815 Chauvin published a work on "Insolation" in which he urged the use of the sun for all diseases associated with feebleness, exhaustion and apathy. The names, however, that stand out most conspicuously in actinotherapy and heliotherapy are Finsen and Rollier. It is mainly through their efforts that it has come to be recognized that sunlight itself or the ultraviolet ray is a very important factor in the treatment of disease and in the development and maintenance of health.

The advent of the sun in scientific medicine is no less glorious than that of the microscope, antisepsis and anesthesia. Its reintroduction into modern therapy is a decided contribution, and constitutes a whole new chapter in the history of medical progress.

The first modern institute for the scientific treatment of disease by means of light was established by Niels Finsen in Copenhagen. For years his work remained unnoticed and unappreciated. After the publication of his book, "Chemische Lichtstrahlen in der Medizin," physicians gradually turned their attention to his methods. Finsen demonstrated beyond doubt that lupus vulgaris, that is, tuberculosis of the skin, can be cured by the action of ultra-violet rays on the affected parts. When Finsen died in 1904 his work had become sufficiently recognized to induce the Danish government to establish the Finsen Medical Light Institute. It is now directed by Dr. Axel Reyn and continues to be a center of attraction for physicians and patients the world over.

Another mighty personality that looms large in the development of sun treatment is Dr. A. Rollier. In 1904 he established an institute for treatment by sunlight. It is situated in Leysen in the Ormonts Valley of the Swiss Alps. His famous sun baths have proved most beneficial to sufferers from chronic ulcers, from anemia and rickets, and from several forms of tuberculosis of the skin, bones, joints and glands.

Rollier has gone even a step beyond attempts to cure. He has entered the more vital field of prevention. Children with reduced powers of resistance brought on by various diseases such as measles and whooping-cough, who are in danger of developing tuberculosis, are boarded at the Rollier school. They conduct their studies in the open air for two hours every day and with clothes consisting of no more than a loin cloth, linen hat and a pair of shoes. They rest for two hours every day and fill in the remainder of their time with nature study and Swedish drill.

Let us delve a little into the nature of sunlight. The ether is traversed by a great variety of electromagnetic waves of various length. The longest of these are the Hertzian waves, the so-called radio waves which possess the ability to carry sound into every home. These

waves may be many miles in length. They are invisible. The next shorter variety of wave-lengths are the infra-red rays of the spectrum. Still shorter waves are the ultra-violet rays and yet still shorter in wave-length are the luminous rays of the sun. The shortest rays are the X-rays or Roentgen rays and the gamma rays from radium.

The unit of measurement adopted for measuring the wave-lengths of various rays is the Ångstrom unit, which represents one ten-millionth of a millimeter. The table below gives the wave-length of the different kinds of rays known.

Kinds of rays	Wave-length Angstrom unit
Gamma rays from radium	0 to 0.1
Roentgen rays	0 to 500
Extreme ultra-violet radiation	0 to 2,000
Middle ultra-violet radiation	2,000 to 3,000
Near ultra-violet radiation	3,000 to 4,000
Visible radiation	7,800 to 5 million
Electric waves, wireless telegraphy, radio waves	5 million units to miles

The emanations from the sun make up a mixture of rays of different wave-lengths. The sun's rays are either visible or invisible. Newton made the pioneer observation that what is called white light consists of a variety of colors, the familiar spectrum when light is passed through a prism. One color differs from another only in wave-length. The white light or visible spectrum is only a portion of the rays coming from the sun. Beyond the visible red rays there is an invisible infra-red region made up of waves of much higher wave-length than the rays of the visible spectrum. Beyond the visible violet rays, there is the ultra-violet region with rays much shorter than the rays of the visible spectrum.

The visible rays produce light and constitute about 14 per cent. of the sun's total spectrum. The infra-red rays produce heat and constitute about 85 per cent. of the sun's output of radiant energy. The ultra-violet rays are the chemical or actinic rays and make up only 1 or 2 per cent. of the sun's rays. The visible portion of the spectrum may be completely shut off, but if a photographic plate is placed in the ultra-violet region it will still become sensitized. The therapeutic properties of sunlight are now believed to reside largely in the ultra-violet rays, although it can not be denied that the infra-red rays as well as the luminous rays are also important from a biologic standpoint.

The quantity of ultra-violet light that reaches a person depends upon many factors. The ultra-violet rays are very readily absorbed. In order to get their biologic benefits very little should interpose between the sun and the surface of the body. Clothes may prevent the ultra-violet rays from reaching us. The shoulder strap of the bathing suit keeps the skin underneath from tanning. Porous, thin and loosely woven clothing presents to us a better chance for the appropriation of these rays. The type of clothes worn by women is better adapted to the reception of ultra-violet from the sun's rays than the type of clothes worn by men.

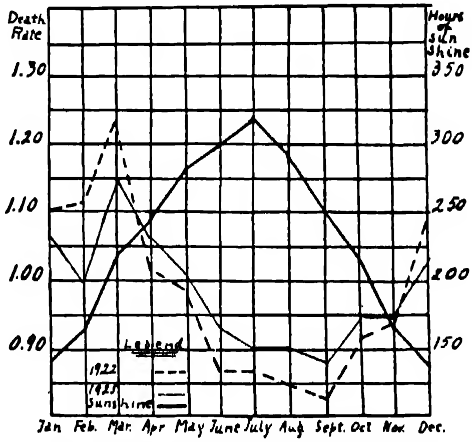
Impurities in the air also conspire to filter out ultra-violet rays. The great offenders in this respect are smoke, fumes, dust, bacteria and moisture. In an industrial center, therefore, less ultra-violet is bound to reach the surface of an individual.

Ordinary window glass lets in the luminous rays but unfortunately excludes the ultra-violet rays. A sun parlor with windows closed is useless so far as the therapeutic value of these rays is concerned. Although ultra-violet prevents rickets, white rats kept in glass

boxes exposed to bright sunlight, nevertheless, develop this disease. In the last few years new types of window glass have been made. These are now being used in some hospitals and sanitaria. A hotel in Chicago has recently equipped its guest rooms with this new type of window glass. There is no doubt that in the very near future the old window glass will be universally discarded for the glass that allows the ultra-violet rays to pass through.

The amount of ultra-violet that finally reaches us depends also on the season of the year. There is much more ultra-violet in the summer months than in the winter months. In July and August the ultra-violet content of sunlight is of maximal value. In December and January the ultra-violet content of the sun's rays is minimal or less than 5 per cent. of its maximal value.

Lack of ultra-violet is believed to be partly responsible for the increased rate in sickness and death during the winter months. The sun is practically darkened for more than half a year. As a result of indoor living brought about by inclement weather during the winter months, the little sunlight available is hardly utilized at all. It is the lack of sunshine that is responsible at least partly for people weakening physically during the winter months and succumbing easily to disease. Pneumonia, influenza and the common cold are most prevalent in those regions where and in those seasons when there is least sunshine. The statistics kept by the U. S. Department of Commerce show an interesting interrelation of mortality rate to sunshine hours. Plotting the curve for death-rate and sunshine hours, let us say for the years 1922 and 1925, we see at a glance that the death-rate increases as the months grow darker and decreases as the sun returns. Even spring fever with its feeling of aimlessness and lassitude arrives at the end of a long period of practically sunless days. The feeling is often noted on rainy or foggy and cloudy days during winter or any other time of the year and is often described as the under-the-weather feeling. It very often disappears with the coming out of the sun.



RELATION BETWEEN MORTALITY RATE AND SUNLIGHT

The fact that the winter months are accompanied by a marked increase in morbidity and in mortality should lead us to the use of artificial sunlight during those months. Especially is such use indicated for people with subnormal vigor and health. Maughan and Smiley have shown that during winter months treatment with ultra-violet reduces the incidence of the common cold about 40 per cent.

Sunlight has many values. It adds considerably to general well-being. It improves the body metabolism. No plant, animal or human being could live without it. It invigorates physically. It enhances mental powers and brings to the front the more positive and stimulating emotions.

The sun's golden lancers
Were watching the dancers
Down in the meadow one day,
When the buttercup said,
"I'll wager my head

I'm brighter than you are to-day."
"And what do you think"
Said the beams with a wink,
"Has made you so strong and so gay?"

Sunlight is a powerful bactericide. It also plays a great part in the development of immunity. It raises markedly our resistance to local or general infection. It helps to build the hemoglobin and the red cells in the blood, and it serves to keep the coagulability of the blood up to normal. It improves the excretory function of the skin, giving rise to a healthy skin, soft, velvety and slightly moist. It keeps the muscles and nerves of the body in tone. It therefore gives bodily poise and prevents overweight. Sunlight is God's way of preventing disease.

Some look for health in pills
And some in rules;
Some grope for it in stuffy,
Cheerless schools,
But from the wind-swept fields,
A voice proclaims
"Your health lies neither there
Nor there, O fools."
Oh contemplate the lilies,
Look I say!
And chase your patent
Humbugs quite away,
The sun had spread her
Golden vesture down,
And bids you to her picnic.
Come and play!

Sunlight has proved of great value in the treatment of disease. Medicine is getting away from drugs. As a matter of fact, the pharmacist is now compelled to make a living by selling articles other than drugs. The prescription counter now occupies a little obscure corner of his establishment. We are getting to rely more and more for the maintenance of health or for recovery from disease upon the three greatest of modern physicians, Dr. Sunlight, Dr. Diet and Dr. Quiet. In tuberculosis, in infantile tetany, in rickets and in anemia, sunlight or ultra-violet has remarkably favorable effects. In the treatment of chronic ulcers of the limbs, and in skin infections, such as acne, boils, carbuncles and lupus vulgaris, sunlight or ultra-violet also serves as a very efficient therapeutic agent. Whenever a tonic is needed, as in acute infection, in convalescence, in muscular weakness, in anemia, in general debility and in neurasthenia, sunlight or ultra-violet can be used to great advantage. In short, sunlight or ultra-violet is a very valuable aid to the progressive physician. We may also state that the infra-red rays are effective in the treatment of muscle pain, rheumatism and arthritis.

In the preparation of a patient for a major or minor operation, sunlight or ultra-violet treatment should hardly be omitted. In the event of a low serum calcium and low platelet count, it raises the coagulability of the blood by increasing its calcium content and the number of blood platelets. It thus prevents excessive losses in blood through unnecessary hemorrhage. By raising the alkaline reserve of the blood it may prevent the post-operative nausea and vomiting, which are symptoms of acidosis. The liberal use of carbohydrate, calcium-rich foods and sunlight or ultra-violet helps very much to prevent risk resulting from surgical intervention.

We have one vitamin, the anti-rickets vitamin or fat-soluble D, that acts biologically in the same manner as the ultra-violet rays. It can, therefore, cure or prevent rickets. This vitamin is not widely distributed in foods and is not very abundant. It is found especially in such fats as are contained in egg-yolk and in liver. Cod-liver oil is a very good source of this vitamin. Vegetable fats have none of it. Recently it has been discovered that exposure to sunlight or to the ultra-violet rays converts foods that allow the development of rickets to foods that cure and prevent rickets and do other things which sunlight or ultra-violet rays are capable of. All foods contain ergosterol or a compound simi-

lar to it. This substance has the power to absorb ultra-violet and to hold it for future biologic use. Several food companies have already caught the possibilities of adding nutritional value to their products and have already put on the market irradiated foods.

A very striking and interesting effect of sunlight or of ultra-violet and even of substances like cod-liver oil that contain vitamin D is its ability to increase the acidity of the stomach. The stomach under normal conditions has a certain amount of hydrochloric acid. This amount of acid serves to destroy bacteria which enter the stomach by way of the mouth and by way of the large intestine. Without this acid or with too little acid in the stomach and intestines, bacteria find their way into these organs, penetrate the walls, circulate in the blood and start an infection somewhere in the body. When a person is unable to disinfect himself on account of insufficient acid in the stomach he is in danger of harboring infection.

The acid of the stomach washes down into the upper part of the small intestine and keeps that part of the alimentary tract in an acid condition. Intestinal acidity is very essential to the health of a person. When the upper part of the intestine is neutral or alkaline, not only does it become highly bacterialized, but the calcium, phosphorus and iron of the food fail to be absorbed and pass out of the body unused.

As a result of inability to use calcium and phosphorus, a child develops rickets or infantile tetany. As a result of inability to use iron a young person or an adult is sure to develop anemia. Anemia in the child or in the adult is more common in winter than in summer. The symptoms of anemia are also severer in winter than in summer.

The value of ultra-violet in the treatment of anemia has again been recently demonstrated at the Iowa State College. Dr. Jongewaard observed that two thirds of the girls coming to the clinic had secondary anemia, the hemoglobin ranging from 50 to 70 per cent. He advised these girls to take a diet rich in hemoglobin-building material, to go to bed early and to stay out of doors as much as possible. He also treated them with ultra-violet rays. His findings have led him to the conclusion that sunshine is a part of nature's mechanism for promoting the assimilation of iron and for the production of hemoglobin and red cells.

Sunlight serves as a mental and emotional stimulant. It has a tonic effect on the mind. Mental tests for children in England attending sun classes bring out the fact that as a result of mere exposure to sunlight the pupils showed marked improvement in mental capacity and in general alertness arising from rapid coordination of thought and action. Sir Henry Gauvain in his work at the Lord Mayor Treolar Cripple's Hospital and College at Alton, England, noted that the London school children and the crippled lads who did not take sun baths averaged one year in mentality behind the tuberculous children who were treated by light.

At the commencement of the sun classes in the English observations, many of the pupils were listless, tired or lazy. As the sun classes continued, they gained in self-confidence, in self-reliance and in powers of observation. They finally developed excellent *esprit de corps,* increased vitality and initiative. Aimlessness and lassitude disappeared and the children manifested a constant craving to tackle a set piece of work and to get it completed.

Sunlight or ultra-violet light also favorably influences the emotions. It exhilarates and induces a sense of gaiety and well-being. It dissipates gloom and depression. Few people commit suicide on days of sunshine. Most of the suicides occur on drab days and during the

sunless winter months. In this connection it is apropos to cite Norman Davey:

> The sun is a dispeller of ill-humor. He is the healer, the life-giver. He is the only true doctor of the troubled mind. He is the best apothecary in the world. There is no tonic sold for gold over any druggist's counter so remedial as that celestial pick-me-up which is poured for nothing each morning over that wide counter which is the brim of the earth.

On the walls of Dr. Rollier's consulting room in his famous light sanatorium the famous inscription is to be read: *De toutes les fleurs la coeur humaine est ce qui a le plus besoin de soleil.*

Keyserling in the "Travel Diary of a Philosopher" exclaims,

> What would man be without sun? He would not exist at all. The whole of his being is sun-produced, sun-born, supported by the sun and withers when the mainspring of life turns away. The more I advance in recognition the more I profess sun-worship myself. During these terrible months when the sun only throws a hasty, disdainful greeting upon Esthonia . . . the curve of my life declines every time. My body feels ill, my vitality decreases, my soul loses in tension. And conversely, periods of my highest creative power always coincide with the longest days.

Youth must live in the light. It is therefore no wonder that great artists have endeavored to depict on the same canvas the spirit of youth and sunshine. Vincent Homer, George Bellows and Frank Benson have awakened through their paintings the longing for the spontaneous enjoyment of outdoor life, of fresh breezes and bright sunny days. Sorolla y Bastida, of Spain, is another painter of sunshine. His magnificent paintings are flooded with it and vibrate with the jollity of youth.

To be out in the open air whenever possible and as long as possible is the great need for every man, woman and child. Too much time altogether is spent indoors. The sun bath is even more essential as a means of conserving health than the water bath. The hundreds of thousands of persons who visit the seashore for the purpose of sea bathing derive great benefit from exercise in the sea water, but much greater benefit from the exposure of their bodies to the sun.

Too many people fail to get the bliss that comes from sprawling on the green turf and playing and working close to Mother Earth. Too many people are ill from sunshine starvation. The individual who thinks that he is out in the open in his closed automobile fails to realize that it is his car and not he that is getting a sun-bath and the beneficent ultraviolet rays. To the great number of invalids who are bedridden we have to add another and surprisingly larger group of individuals who are auto-ridden.

No wonder that Richet called man "homo stultissimus," or "idiot-man," because, having knowledge of the prevention of disease, he does not apply that knowledge to the best of his advantage.

A CAPTIVE-BORN CHIMPANZEE

By BESSIE A. WHITE

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"THERE he is, and I wish you luck!" With these cheering words did a tired and nerve-wracked keeper place in my outstretched hands 1,720 grams of cold, starved, cage-dirty anthropoidism, just forty-eight hours old, and with forty-nine centimeters of atrophied umbilical cord still attached. Two days before, on October 1, 1928, our fine, big chimpanzee, Marianne, had given birth to this baby, and although she seemed to be a very tender and adoring mother and very solicitous of her offspring in all other ways, she made no attempt to nurse it or even to take it up in her arms. She herself missed not one feeding, even the day it was born. She sat by it, crouched in a protecting attitude, and when she did move away, the faintest whimper brought her hurrying back to nuzzle it and respond to its cries with a soft, purring note. For two days she was left undisturbed, in the hope that the nursing instinct would develop sufficiently to prompt her to take the little one up against her breast; but as the little body grew steadily colder and the cries weaker, it was decided to take him from her and try artificial rearing. The little mite was apparently oblivious to his surroundings, but even as I softened with vaseline the dried accumulations of meconium, and prepared to wrap him in wool flannel, he clutched my apron with a strong grip, which little act promptly transformed him, in my mind at least, from a newborn chimpanzee to a forlorn little baby, desperately in need of a mother. A full scientific description of his size and general appearance at this time will be found in an article by Dr. Herbert Fox, "The Birth of Two Anthropoid Apes," *Journal of Mammalogy,* February, 1929.

After one and one half hours exposure to a warm October sun, a rectal thermometer was inserted. It did not register. External heat was applied in the form of hot water bottles, and the little body was held in a warm oven several times for two or three-minute intervals. Later an electric stove was placed so the heat was reflected directly upon him. At 4:00 P. M., the thermometer was again inserted, with the same result. The external heat was continued, however, and by 5:30 P. M., he was perceptibly warmer. His temperature at this time was 97.6° F.

He voided urine frequently, but had no further stool after being taken from the mother until he was given a half teaspoonful of milk of magnesia on his fifth day. This brought a large, dark brown stool, showing traces of meconium. From then on, all stools were of a bright yellow, soft-formed, and averaging three of about two ounces each in twenty-four hours.

Feeding for the first forty-eight hours after he was received at the laboratory was by means of a medicine dropper, swallowing being induced by tipping the head back or massaging the throat, sometimes both. Some of the first few feedings were regurgitated, but by evening he was retaining all of it. On the advice of Dr. J. C. Gittings, he was given evaporated milk diluted with six parts of water, one half ounce being all he could be induced to take at a time. This was given every two hours, day and night. Early on the third day of this artificial feeding, he suddenly began searching excitedly with his mouth. Lest he lose the inspiration, an empty nipple was quickly thrust between his parted lips. He sucked vigorously for a

minute while a hastily prepared bottle was being attached to the nipple. His medicine dropper feedings were over. The attention he gave that bottle would please the most anxious mother. At the age of one week, he was taking from ten to twelve ounces of diluted milk in twenty-four hours.

During the first three weeks, he lost weight, dropping from 1,720 grams to 1,440 grams. On the twentieth day, one half teaspoonful of cane sugar was added to the daily quantity of milk formula, and at the age of four weeks, he weighed 1,574 grams; at the end of the second month, 2,136 grams; third month 2,514 grams; fourth month 2,923 grams; fifth month 3,220 grams; sixth month 3,544 grams. Experience showed that the sugar, while it seemed to promote a gain in weight, could be increased only very gradually, and at the first sign of diarrhea was cut entirely until the stools were again normal. At the age of six months, one and one half teaspoonfuls to the daily quantity of formula, twenty ounces, seemed the proper amount.

Early in January, raw, unpasteurized milk, diluted to correspond with the evaporated milk formula, was substituted for one feeding a day. As no unfavorable results followed a few days of this, the raw milk was used exclusively thereafter, with the exception of a few days when it was deemed wiser to boil the milk because of a slight diarrhea.

At the age of four and one half months, a tablespoonful of oatmeal gruel was added to one feeding a day, and two weeks later, the yolk of an egg was added to the day's formula twice a week. Vegetable purees were then tried, first spinach and, later, pea, but these were effectively scorned. Nor did these latter foods meet with any greater favor with our older chimpanzee "Lizzie" and the gorilla.

Considering the six months as a whole, there was really very little trouble with the digestive tract, and, as we learned later, the development of bone and muscle was progressing very satisfactorily. During October, his first month, and occasionally during November, it was possible to give him the benefit of direct sunshine for short periods, but with the exception of a few mild days in February, it was necessary to suspend this during the winter months. In the absence of definite records of teething in the chimpanzee, at least it can be said that this was proceeding normally, although perhaps a bit retarded, due to lack of natural feeding.

During the fifth month, when he was making definite attempts to draw the bottle to his mouth unaided, care was taken that both hands were left free. Almost every time he used the left hand, even though he did not attempt to clutch anything with the right at the same time. The question rises—was the right, from instinct, left free for emergencies, such as falling or sudden need to move? Very early, it was learned that he could take his bottle much more comfortably if held in an upright position. At such times he kept a firm grip on the clothing of nurse or keeper, but as he grew older this clutching instinct gradually diminished, as though he no longer feared falling.

During the latter part of the first month, orange juice and cod-liver oil were added to his diet in small amounts. This resulted in intestinal disturbances, as did subsequent attempts. During the third month, however, the results were more favorable, and by the end of the third month, he was taking one half teaspoonful of orange juice and ten drops of cod-liver oil daily.

Early in December he was drooling at the mouth after the manner of teething babies: His first tooth, the right lower incisor, appeared January 29, when he was almost four months old. The left was through February 16. Nearly a month later, March 13, the right upper incisor was plainly felt, fol-

lowed ten days later by the left. Three days later, the lower left lateral incisor appeared, and the right was all but through at the time of his death on April 12. During this teething period he seemed anxious to bite on any firm substance within reach, but at no time was there any marked swelling or other sign of undue inflammation.

During the early weeks, although his eyes were wide open and bright, he was apparently incapable of focusing his vision. His hearing and sensitiveness to touch, however, seemed very acute. At the slightest sound or the most careful adjustment of his covers, he would start violently. At the end of the first month, his eyes seemed to have more expression and he appeared to be beginning to correlate sight and sound. If a person stood at the foot of his basket and talked to him, his eyes would be directed at that person. If the person moved away, but ceased talking, his eyes would remain directed as before; but if the person resumed speaking after moving, the baby's eyes would almost invariably follow the sound. At the age of six weeks there seemed to be no doubt that he could focus his vision.

By the time he was two months old, he would frequently give a short responsive bark or grunt when spoken to, and sometimes tried to imitate the "ooh-ooh-ooh" of his elders. He seemed to enjoy attention just as a human baby does, and favored us with his first smile at the age of six weeks. Whether he preferred men to women it is impossible to state, but certainly he responded more readily to a man's voice than to a woman's.

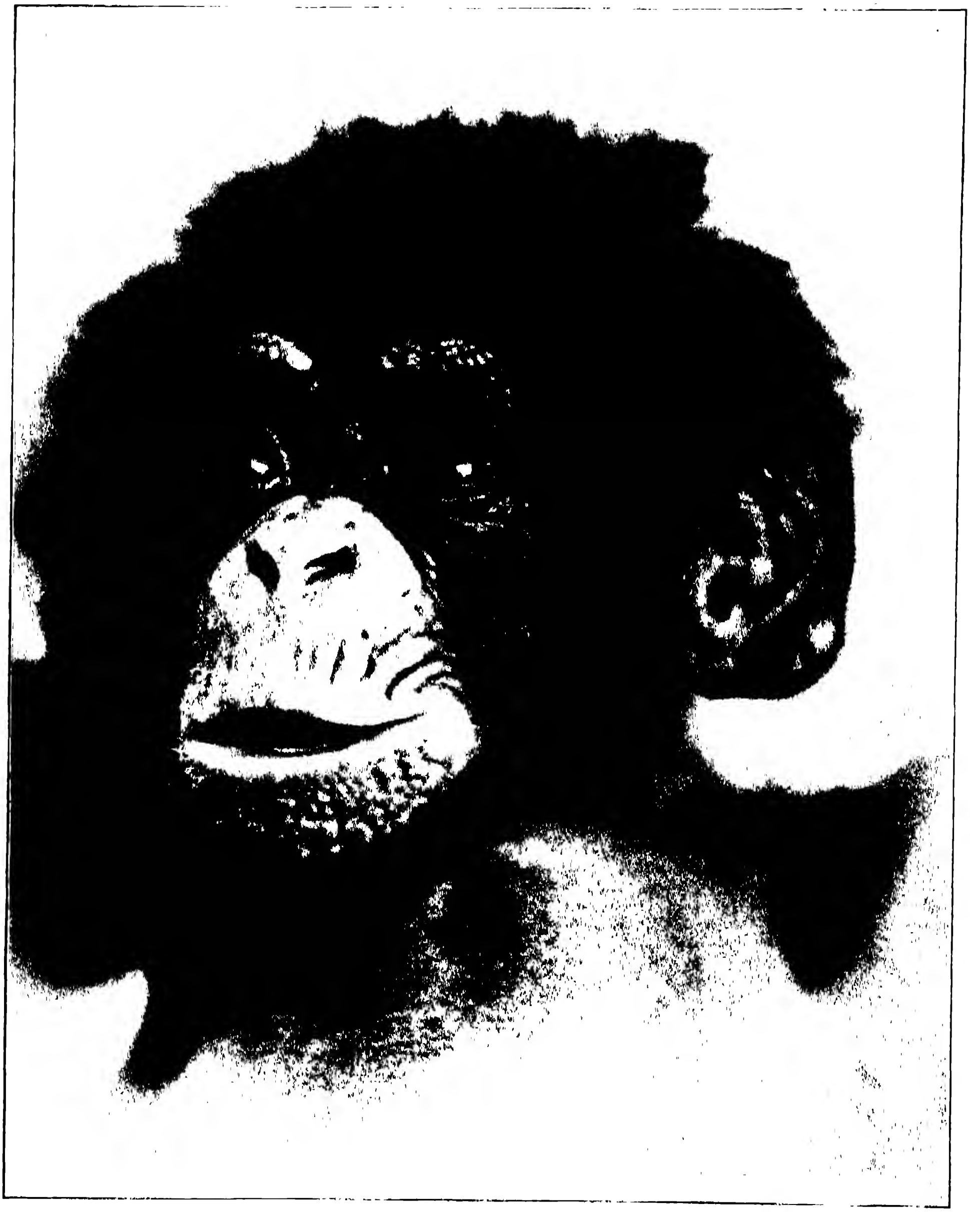
By this time he had developed a vigorous temper, and did not hesitate to display it if his bottle was too long delayed to suit him. He would start with a series of grunts, which would soon reach a high-pitched "ooh-ooh-ooh," and then a succession of shrill screams so intense that they usually choked him into a few seconds of breathless silence. As soon as he recovered his breath, the same tactics were resumed until the desired bottle was forthcoming. At this age he seemed to recognize the keeper and me, regardless of whether we were in our working uniforms or in street clothes.

He certainly seemed to have two types of response when spoken to. To Mr. McCrossen and myself, and a few others, he returned a soft, sometimes throaty, "ooh-ooh-ooh," but to certain others he replied with a sharp, excited bark, which must have been indicative of dislike, because later when one of these men had part of the care of him, he gradually tempered his response to him from the shill bark to the friendly greeting that he reserved for those who had the more intimate care of him.

Nor were his discriminatory powers limited to persons. He very early learned to associate a spoon with cod-liver oil, and fought vigorously against taking anything by that method, unless "primed" by a taste from a finger dipped in the food.

During the first few weeks, he would lie in his basket in the position in which he was placed, but soon showed a decided preference for lying on his back. He liked to be held, his favorite position being upright against a person's shoulder. During the fifth and sixth month, he remained awake much more during the day, and then would frequently turn from his back to his side and back again in his play, often pulling on a bar or other object to help himself over. Bits of rope, some with teething rings or other toys tied to them, were suspended within convenient reach, and these also were frequently used to help himself about. A popular position was to turn on his side and raise his head and shoulders, supporting himself on his forearm.

In the matter of activity and development of locomotive powers, this baby probably missed his mother fully as



THE CHIMPANZEE, "JULIUS," AT THE AGE OF SIX WEEKS

THIS SHOWS WELL THE SKIN FOLDS AND FACIAL FORMATION. THE VERY LONG HAIR IN THE FRONTAL REGION WAS SHED OUT IN A FEW MONTHS AS INDICATED BY THE OTHER PHOTOGRAPH.

much, if not more than in the matter of nourishment. The baby orang-utan, "Lucky," only six days older than this baby chimpanzee, "Julius," was able at the age of three months to cling to the bars with all four limbs, and get about by himself as far as his solicitous mother would permit. "Julius," on the other hand, missed the rough-and-tumble handling that was the lot of the little orang-utan from his second day in the world, when the mother orang calmly draped him across her hip and left him to cling for himself while she moved about the cage. This enforced use of his muscles certainly must have gone far toward developing them. Nor does he seem to resent this schooling in self-reliance. If he crawls too far away to please "Maggie," his mother, she reaches out with either arm or leg, grasps him by the most convenient part and retrieves him. I have seen her cup her two feet about his little head and pull him. At such times he evidently thinks co-operation is the wisest policy, because he usually grasps her hair, thus relieving the traction on himself. All this gymnastic play little "Julius" missed, because monkey-house keepers and laboratory assistants, as a rule, do not have as much spare time as does a captive orang.

Scratching—characteristic of all animals, but perhaps more closely associated with the primates—was first noticed in this chimpanzee at the age of three and one half months, feeble but unmistakable. It would seem that this must have been an impulse of the fingers rather than the consciousness of any need of it, because he would perform the same service on the arm or face of a person holding him and with equal attention to technique. During the first six weeks, he would all too frequently scratch his face in an alarmingly vigorous, but altogether different manner. The outspread palm would, either by intention or accident, come in contact with his face, and immediately the flexed fingers would be drawn down the face as though to pull away something that might be annoying him or obstructing his vision. This resulted in many little abrasions, one of which, at the left side of the base of the nose, after many disturbances of the scab, developed into one of the dark pigmented spots so common on the faces of these animals. There may be some significance to the fact that after the power of focusing his vision seemed definitely established, this little mannerism of face scratching ceased.

No human baby ever enjoyed the exquisite flavor of his toes any more than did this tiny ape. As soon as the early morning bottle was finished and he was returned to his bed, he always managed to capture one foot, and holding it to his mouth with both hands, would bite and suck on it to his heart's content. During the process of restoring the laboratory work-room from an improvised nursery to its normal appearance, it was difficult to pass his box without pausing for a word. Immediately the foot was withdrawn from his mouth and I was greeted with a face-wide smile, usually the foot being generously offered to me for a taste. However, when I appeared at his side with my coat on, the signal that he was about to be taken back to the monkey house for the day, all play was promptly abandoned and he immediately became very tense. If I didn't take him up at once, he would hold up both arms, purse his lips and begin a soft "ooh-ooh-ooh," a perfect picture of anxious pleading. Whether the presence of the coat had any effect on him or not, it is impossible to state. The interval between the first bottle and his removal to the monkey house was about the same each day. Perhaps it was coincidence that he was tired of lying in his box after that length of time, and wanted to be taken up. Again, perhaps he had learned to look for that little inci-

THE CHIMPANZEE "JULIUS," AT THE AGE OF FOUR AND ONE HALF MONTHS
THIS WAS THE EXPRESSION WHEN THE ANIMAL WAS PLACID. IT SHOWS VERY WELL THE FORM OF FIST-MAKING

dent in his daily routine just as he looked for his feeding. On the other hand, no matter how many times I stopped at his box, he seemed contented to lie there and play until I appeared with the coat on. When the return trip from the monkey house to the laboratory was made in the evening, he was usually asleep, and roused only partially as he was taken up.

This fascinating picture of babyhood, differing from the human only anatomically, was progressing serenely until the end of the sixth month, when clouds appeared on the horizon. A restless night—fever—two weeks of illness and suspense—and on April 12, the soul of the only captive-born, bottle-fed chimpanzee on record swung back to the celestial jungles, leaving the little body to pathology, zoology and all the various other "ologies" so dear to science.

The first question that rises in the mind of the reader—and naturally—is, why was the bottle feeding necessary? Why did not the mother ape suckle this baby? Many theories have been advanced, but none can be proven the correct one. The smaller, old world monkeys are known to eat the placenta shortly after it is expelled. This mother, "Marianne," did not eat the placenta at this birth, nor did she offer any objection when it was removed from the cage nearly two hours later, although

she had very evidently mouthed it, perhaps sucked blood from it, as shown by blood on her face after having her head down in the straw where it had fallen, and also by tears in the afterbirth. Neither did "Maggie," the orang-utan mother, make any attempt to eat hers, but simply severed the cord with her teeth after approximately twenty-eight hours and pushed the placenta over against the door of her cage, as she might do with anything she didn't want. Lactation in "Maggie" has apparently been entirely normal, and she has been a model mother. Dr. H. H. Donaldson, when consulted in the matter, expresed the opinion that perhaps the presence of visitors and members of the Garden personnel may have disturbed "Marianne" by depriving her of the privacy she might be expected to seek. However, both the inner and outer cages have dens to which she could easily have retired had she so desired; but when it was known beyond doubt that she was in labor, she still remained in the most exposed part of her quarters. Dr. Donaldson suggested further that the separation of the male and female at almost the height of labor might have frightened her and made her unduly apprehensive. It is highly probable that "Marianne's" neglect was due to a combination of causes and it is the opinion of the writer that her youth was no small factor.

That she was not entirely lacking in maternal instinct is shown by the fact that she cuddled and mouthed the baby, showed deep concern and solicitude when he cried, and resented his being taken from her. Mr. J. L. Buck, who brought her from Africa when she was approximately three years old, tells how at that time she "mothered" a smaller chimpanzee in the same group, cuddling him to her breast and struggling valiantly to carry him about, even though he was not a great deal smaller than herself, and well able to walk. Her own offspring she made no attempt to pick up.

In like manner "Josephine," another chimpanzee, presented to the Zoological Gardens by Mr. Alfred M. Collins, "mothered" little two-year-old "Napoleon" when he was allowed in her cage. At first, the little fellow's visits were necessarily limited, lest he become too tired from the unaccustomed excitement and play. "Josephine" soon learned that attempts to entice one or the other of them into another compartment of the cage were for the sole purpose of separating them, and she was always on the alert to prevent this. I have seen her take up a position beside him so that he was near her hip, give a low bark and wait; but "Napoleon" continued with his play. She turned, gave him a sharp slap on the back of the head and resumed her position of waiting. "Napoleon" was evidently satisfied where he was, but thoroughly understood what was expected of him. He beat the floor with his hands and screamed a few times to register his protest, but nevertheless scrambled hastily to her back and was borne away to the outside cage.

For some time before "Josephine" came to the Garden, she had had a Schmidt's monkey as a cage mate. This little creature also served as an outlet for "Josephine's" maternal instinct. She carried him about, clinging to her breast, wherever she went. One night they were placed in separate cages, but morning found both cages broken open, and "Josephine" cuddling her adopted baby as usual. "Josephine" was unquestionably a nullipara, having been brought from Africa before she was fully adult; but the maternal instinct was surely a large part of her emotional make-up. Unfortunately it was not possible to give her an opportunity to breed in the three and one half years she lived at the Zoo.

However, the instinct to cuddle and protect the young seems not confined to the females. The above-mentioned "Napoleon," now about four years old, when allowed to approach this baby of his own kind, immediately tried to take it up. When he found this was not allowed, he put both arms around it and patted it gently. When the baby cried, he tightened his embrace and speeded up the patting. The baby grasped the hair on his arm, and although "Napoleon's" attention was soon attracted elsewhere, he held the captive arm perfectly still and made no attempt to free it from the baby fingers. On the other hand, as one baby to another, these apes seem all too human. Little "Orphan Annie," the year-old orang-utan, was not so gentle, and while she would touch him very gently at first, she would slyly watch for a chance to pull his arm or leg; but her chief delight was to steal his covers with which she immediately proceeded to adorn herself. The baby himself watched these other animals very solemnly and made no attempt to play with them.

When this baby chimpanzee was shown to his mother for the first time after removing him from her cage (about two months later), she came forward to the bars, gave a few short barks and gazed intently at him. The same thing happened on two or three subsequent occasions, but after that "Marianne" simply gave him a bored look and continued what she had been doing.

Despite his mother's indifference, this little ape seemed to thrive very well under artificial feeding, because after death it was discovered that bony and muscular development was all that could be expected in a normal breast-fed animal. We take this as an indication that our attempts to approximate his normal alimentary needs were successful. His death was due to an acute infection that not infrequently attacks even the most carefully guarded, breast-fed human babies. A detailed account by Dr. Fox of this final illness and the findings at autopsy will appear in the Zoological Society's laboratory report for 1930.

—Bachrach

A RECENT PHOTOGRAPH OF MR. EDISON

THE PROGRESS OF SCIENCE

IN HONOR OF MR. EDISON[1]

THIS ceremony is a part of the celebration of Mr. Edison's invention of the electric lamp. It is also the dedication of the Edison Institute of Technology, the gift of Mr. Ford. Both are in fact national tributes to Mr. Edison.

The multiplication of the amount of light in the world a thousandfold is worthy of celebration, for darkness is a forbidding limitation upon righteous human activities.

When Mr. Edison invented the electric lamp he may perhaps have thought just to produce plain light and more of it at less cost. I surmise that his wildest ambition was to relieve the human race from the curse of always cleaning oil lamps, scrubbing up candle drips and everlastingly carrying one or the other of them about. He may have thought to add safety to Chicago against a second accident from an oil lamp.

But the electric lamp has found infinite variety of unexpected uses. It enables us to postpone our spectacles for a few years longer; it has made reading in bed infinitely more comfortable; by merely pushing a button we have introduced the element of surprise in dealing with burglars; the goblins that lived in dark corners and under the bed have now been driven to the outdoors; evil deeds which inhabit the dark have been driven back into the farthest retreats of the night; it enables the doctor to peer into the recesses of our insides; it substitutes for the hot-water bottle in aches and pains; it enables our cities and towns to clothe themselves in gaiety by night, no matter how sad their appearance may be by day.

And by all its multiple uses it has lengthened the hours of our active lives, decreased our fears, replaced the dark with good cheer, increased our safety, decreased our toil and enabled us to read the type in the telephone book. It has become the friend of man and child.

In making this, as in his other great inventions, Mr. Edison gave an outstanding illustration of the value of the modern method and system of invention, by which highly equipped, definitely organized laboratory research transforms the raw material of scientific knowledge into new tools for the hand of man.

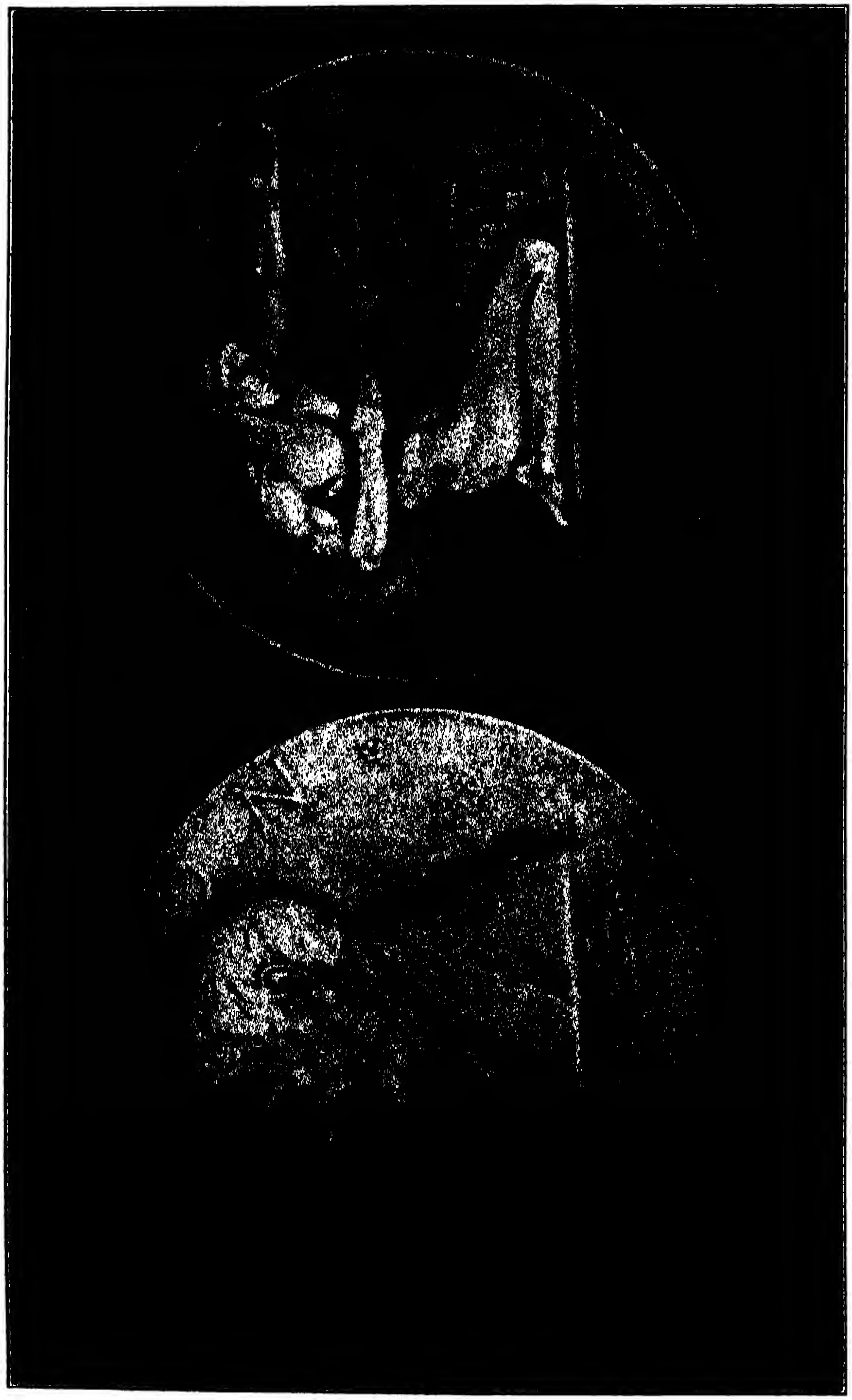
In the earlier times, mechanical invention had been the infrequent and haphazard product of genius in the woodshed. But science has become too sophisticated a being to be wooed in such surroundings. Nowadays a thousand applied science laboratories, supported by industries of our country, yearly produce a host of new inventions.

I can perhaps illustrate this modern method of invention. The fundamental natural laws of electricity were discovered three quarters of a century ago by Faraday, Hertz, Maxwell and other great investigators in the realms of pure physics and mathematics. Faraday discovered that energy could be transformed into electricity through induction — the theory of the electrical generator. It was one of the momentous discoveries of history.

It is related that Mr. Gladstone was induced to visit Faraday's laboratory to see this new scientific contraption. When Gladstone is said to have made the characteristic practical man's inquiry, "Will this ever be of use to mankind?" Faraday replied, "Some day you will collect taxes from it."

Mr. Edison, using organized systematic laboratory research, has been one of the great leaders who have converted the pure physics of electricity into a taxable

[1] Address given by President Hoover at Dearborn, Michigan, on October 21.



—*Associated Press*

CONGRESSIONAL MEDAL STRUCK IN HONOR OF THOMAS ALVA EDISON

product. To-day the governments of the world levy upon upward of $60,000,000,000 of new wealth founded upon electricity.

But the taxes and new wealth are not the major accomplishments of the men of this genus. These are the rivers of sweat saved from the backs of men and the infinite drudgery relieved from the hands of women.

I may emphasize that both scientific discovery and its practical application are the products of long and arduous research. Discovery and invention do not spring full-grown from the brains of men. The labor of a host of men, great laboratories, long, patient, scientific experiment build up the structure of knowledge, not stone by stone, but particle by particle. This adding of fact to fact some day brings forth a revolutionary discovery, an illuminating hypothesis, a great generalization or a practical invention.

Research both in pure science and in its application to the arts is one of the most potent impulses to progress. For it is organized research that gives daily improvement in machines and processes, in methods of agriculture, in the protection of health and in understanding. From these we gain constantly in better standards of living, more stability of employment, lessened toil, lengthened human life and decreased suffering. In the end our leisure expands, our interest in life enlarges, our vision stretches. There is more joy in life.

It is the increasing productivity of men's labor through the tools given us by science that shattered the gloomy prophecies of Malthus.

More than a century ago that great student held that increasing population would outrun the food supply and starvation was to be the inevitable executioner of the overcrowded earth.

But since his day we have seen the paradox of the growth of population far beyond anything of which he ever dreamed, coupled at the same time with constantly increasing standards of living and ever-increasing surplus of food. Malthus was right except for a new contestant in the race with his principle: That was more scientific research, more discovery. And that race is still on. If we would have our country improve its standards of living and at the same time accommodate itself to increasing population we must maintain on an even more liberal scale than ever before our great laboratories of both pure and applied science.

Our scientists and inventors are amongst our most priceless national possessions. There is no sum that the world could not afford to pay these men who have that originality of mind, that devotion and industry to carry scientific thought forward in steps and strides until it spreads to the comfort of every home, not by all the profits of all the banks in the world can we measure the contribution which these men make to our progress.

And they are the least interested in the monetary results. Their satisfactions are in their accomplishment—in the contribution of some atom of knowledge which will become part of the great mechanism of progress. Their discoveries are not the material for headlines. Their names are usually known but to a few. But the nation owes them a great honor and is proud to demonstrate through Mr. Edison to-day that their efforts are not unappreciated.

The country can well pay its tribute to the men of this genus by expanding the facilities for their labors. The nation to-day needs more support for research. It needs still more laboratories. To that Mr. Ford is making a generous contribution.

And in establishing this institute, Mr. Ford is doing honor to Mr. Edison in a manner which appeals to a sense of fitness—that is, by founding an institution

MME. CURIE AND PRESIDENT HOOVER

A photograph taken at the building of the National Academy of Sciences where President Hoover presented Mme. Curie with a fund for the purchase of radium

dedicated to education and scientific research.

And scientific research means more than its practical results in increased living comfort. The future of our nation is not merely a question of the development of our industries, of reducing the cost of living, of multiplying our harvests or of larger leisure. We must constantly strengthen the fiber of national life by the inculcation of that veracity of thought which springs from the search for truth. From its pursuit we shall discover the unfolding of beauty, we shall stimulate the aspiration for knowledge, we shall ever widen human understanding.

Mr. Edison has given a long life to such service. Every American owes a debt to him. It is not alone a debt for great benefactions he has brought to mankind, but also a debt for the honor he has brought to our country. Mr. Edison by his own genius and effort rose from modest beginnings to membership among the leaders of men. His life gives renewed confidence that our institutions hold open the door of opportunity to all those who would enter.

Our civilization is much like a garden. It is to be appraised by the quality of its blooms. In degree as we fertilize its soil with liberty, as we maintain diligence in cultivation and guardianship against destructive forces, do we then produce those blossoms, the fragrance of whose lives stimulates renewed endeavor, gives to us the courage to renewed effort and confidence of the future.

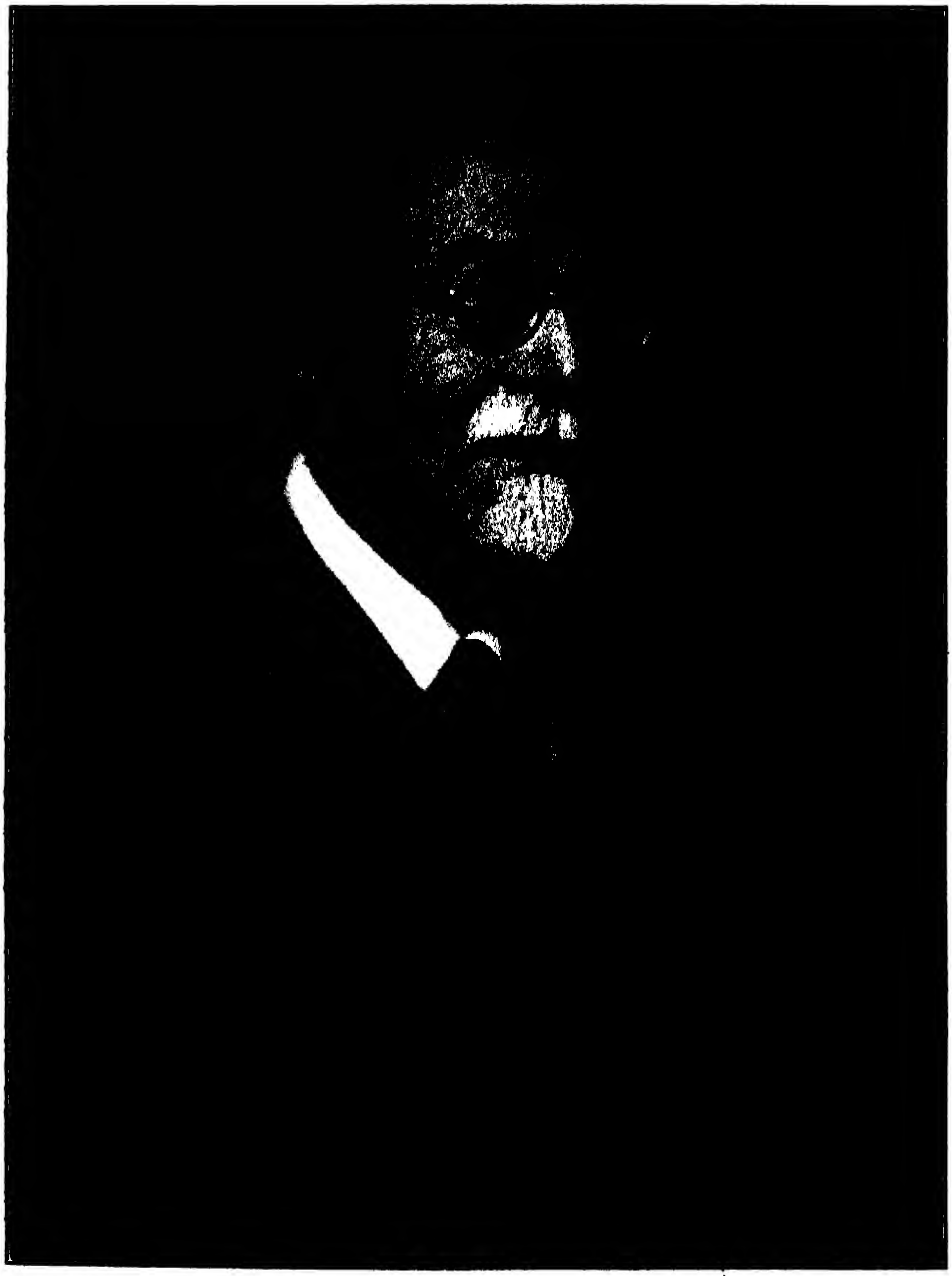
THE AWARD OF THE FREDERIC IVES MEDAL TO PROFESSOR NICHOLS

The Optical Society of America at its recent meeting at Cornell University, October 24 to 26, awarded the Frederic Ives medal to Professor Edward L. Nichols, professor emeritus of physics at Cornell University. This medal was endowed in 1928 by Dr. Herbert E. Ives, in honor of his father, Mr. Frederic Ives, distinguished for his pioneer contributions to color photography, photograving, three-color process printing and other branches of applied optics. It is awarded biennially for distinguished work in optics. Professor Nichols, one of the five honorary members of the Optical Society, is the first recipient of the medal. The presentation took place at a dinner arranged jointly by the Optical Society of America and the colleagues of Professor Nichols on the faculty of Cornell University.

Professor Nichols' contributions to science and his activities in connection with American scientific societies are so well known as to require only passing comment. After receiving the B. S. degree at Cornell in 1875, he studied successively in Leipzig, Berlin and Göttingen, from which latter university he received the doctorate in 1879. He was a fellow at Hopkins in 1879–80, and for a short time thereafter was associated with Edison in the development of the incandescent lamp, particularly with reference to photometric methods of measurements of candle-power.

After serving as professor of physics successively at the University of Kentucky and at the University of Kansas, Professor Nichols was called to his alma mater as professor of physics in 1887, which post he still holds, becoming professor emeritus in 1919.

During the period of thirty-two years from 1887 to 1919 while he was director of the department of physics at Cornell University, there passed through the department a large number of graduate students and instructors who now hold positions of responsibility throughout the entire country. A large number of these returned to Cornell to attend the



PROFESSOR EDWARD LEAMINGTON NICHOLS

THE FREDERIC IVES MEDAL AWARDED TO PROFESSOR NICHOLS

physics conference and reunion upon the occasion of Professor Nichols' retirement as director in 1919.

Professor Nichols is a member of many scientific societies, including the National Academy of Sciences; the American Association for the Advancement of Science, of which he was president in 1907; the American Physical Society, of which he was president in 1907–09; Sigma Xi, of which he was national president in 1908. He was active in founding the American Physical Society and was instrumental in starting the *Physical Review*, the outstanding journal of physics in America.

His first paper was published in 1879. In the intervening fifty years there has been scarcely a year during which he has not published several papers, as the results of his own investigations and with various collaborators, in the fields of photometry, spectrophotometry and luminescence, to which latter subject he has devoted a very large proportion of his attention during the past twenty-five years. Although he became professor emeritus ten years ago, he is still as busy as ever with his collaborators in the physics laboratory at Cornell University extending his investigations in this important field.

With the assistance of Professor H. L. Howes and Mr. D. T. Wilber, Professor Nichols published in 1928 a 350-page report of his work on cathodo-luminescence and the luminescence of incandescent solids, a field in which he has been at work for a number of years. This report is remarkable in several ways. It presents a vast amount of information on this very complex subject on the basis of which, in due course, theories will doubtless be built. Of more significance, however, is the fact that a large part of this work has been either done by Professor Nichols personally or directed by him since his retirement from active service ten years ago. Indeed, it is one of the great sources of inspiration to those of us who have had the great good fortune to be colleagues of Professor Nichols in the physics laboratory at Cornell University to see him maintain, even with increased vigor, his activities in research subsequent to his retirement. Many regard the accomplishments of these last ten years as representing the best work of his long and distinguished career.

However much Professor Nichols is esteemed as a scientist by those who have worked with and under him or have watched his accomplishments from the

outside, still more striking are his personal qualities as seen by those who have had the rare privilege of knowing him as a man. His elementary lectures to undergraduates were always fascinating but many a student has stated that he carried away from the lecture room something far more valuable than the information so clearly imparted by this skilled teacher over the lecture table. There was about his lectures a quiet dignity, an unaffected simplicity, a respect for and a love of all knowledge, which could not but be infectious. Graduate students and the younger members of his staff have profited still more from these rare qualities of his by virtue of their closer contacts with him.

A single instance out of my own personal experience will suffice to indicate the basis of the love and esteem with which Professor Nichols is regarded. When I came to Cornell as an untutored freshman I had a hazy notion that I wished to study electricity, and I made my way to the physics building for advice. Upon entering the hall, the first person whom I saw was the man who, as I learned later, was head of the department, Professor Nichols. I asked if I could find some one who could give me advice with regard to the courses of study which I should take in order to become acquainted with the field of electricity. Instead of referring me to some one else, he immediately, in the most kindly and unreserved yet dignified manner, asked me further about my plans and desires. His attitude was so sympathetic and so full of cordiality, yet without the slightest suggestion of condescension, that I was at once possessed of a desire so to shape my undergraduate course as to come more directly into contact with this man. In a very few moments he outlined to me a course of study which I should follow—and which indeed I did follow almost without change. Further, he gave me, a student quite unknown to him, a cordial invitation to come to him at any time in connection with my course of study. Had I never met Professor Nichols again, those few moments would have stood out in my memory as among the most inspiring of a lifetime. But subsequent contacts in the department later as a graduate student, instructor and member of the staff have been even fuller of inspiration and encouragement.

Every one who has worked with or under Professor Nichols can relate similar instances—all of which serve to explain the veneration in which this great scientist and teacher is held by those who have been associated with him.

F. K. Richtmyer

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